BRITISH SOCIETY
FOR THE
STUDY OF ORTHODONTICS

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Transactions of the

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THE EFFECT OF THE MILWAUKEE BRACE ON THE DEVELOPING DENTITION

By W. RUSSELL LOGAN, O.B.E., T.D., L.R.C.P. & S., F.D.S., D.D.O.

Scoliosis is persistent lateral spinal curvature. It has been classified as developmental, paralytic, or idiopathic. The condition is usually progressive during the period of growth and is related to the upright position of man. Scoliosis is never seen in the lower animals, and, indeed, cannot be experimentally induced.

As the trunk shortens due to the increased angulation of the curve it may do so to such a degree that the function of the viscera is upset. Digestion and respiration are impaired, and in most extreme cases the vital functions may become so hampered that life becomes impossible and the patient dies. This is particularly liable to happen in the paralytic scoliosis following poliomyelitis if the respiratory muscles are more or less damaged. The deformity in scoliosis tends to increase until the spine is mature, and growth ceases about the age of 14 years. The treatment of scoliosis has always been considered difficult and unsatisfactory. Fundamentally, what is required is to straighten the spine, hold it in that position until growth has ceased, and then to fuse the joints in the defective vertebræ, thus producing a rigid bar of bone which does not change its shape under muscular stress or the effect of gravity. The problem lies in the difficulty of distracting the spine and in its maintenance in the distracted position until fusion is possible on the cessation of growth. The magnitude of the problem may be gauged when it is realized that in some cases the curvature becomes apparent as soon as the child can sit up, about the age of 2 years, and is progressive. Various kinds of support have been used, the most effective being those made of plaster-of-Paris. They have the disadvantage of unwieldiness and of considerably hampering the child's activities, as they usually necessitate confinement to bed. One of the types of plaster jacket used is that of Risser, which consists of a hinged plaster shell enclosing the trunk and contacting the skull at occiput and lower jaw, with a turnbuckle on the concave side of the curve by which the trunk may gradually be straightened. Once straight, the correction is held by the use of a new plaster jacket applied to the trunk during distraction and including the pelvis below and occiput and lower jaw above. A window may be cut in the back of the jacket by which access is provided to allow the operation of spinal fusion to be carried out without moving the patient from the plaster jacket.

In 1944 Blount and Schmidt, of Milwaukee, demonstrated a brace which was much less bulky than the plaster jackets and more effective than the jackets of lighter materials then used. In Blount's words, as quoted by Osmond-Clarke, "the brace requires considerable skill and meticulous care in construction and in fitting. It grips the pelvis snugly and the chin and occiput rest on a head piece. A pressure pad exerts a thrust against the ribs on the convex side of the curve, and the jacket can be lengthened by turnbuckles on each side. The patient must be able to raise the chin and occiput simultaneously from the head support to move his trunk away from the pressure pad. Though exerting no forcible traction effect it will be noted that the patient is constantly attempting to correct the deformity by his efforts to lift his head off the support or move his body away from the pressure pad. When an operation is desirable the brace is removed and reapplied immediately after the operation. Prolonged use of the brace sometimes gives rise to malocclusion and prominence of the upper incisor and canine teeth, but this is a small—and correctable—price to pay in exchange for the prevention of a severe scoliosis."

Presidential Address given at the meeting held on Jan. 8, 1962.

A scoliosis clinic was recently established by Professor J. I. P. James on his appointment to the Chair of Orthopædics in the University of Edinburgh. In March, 1960, he asked me, as Dental Surgeon to the Princess Margaret Rose Orthopædic Hospital, to examine a patient who was under treatment for scoliosis and who was showing signs of malocclusion. This child, at the age of 2 years, had been observed to have a spinal curvature. She was also noticed to have brown pigmented areas on the skin. By the age of 4 years, despite the use of various supports and the use of a Milwaukee brace worn only by day, it was found that the curvature was getting steadily worse. It was also noted at that time that she had a prognathic jaw and that the deciduous incisors showed protrusion. Radiographic examination showed lesions typical of neurofibromatosis. In this condition, it will be remembered, a variable amount of the bone tissue may be replaced by neurofibromatous tissue. In August, 1959, she was placed in a distraction jacket and by November the curve was fully corrected. A spinal fusion was carried out between the 4th thoracic and 1st lumbar vertebræ and a Milwaukee brace was again fitted. In March, 1960, a revision of the operated area was carried out, when it was noted that the graft was soft. It was at this stage that I was asked to see her. She presented a remarkable facial appearance, with the chin and nose very much closer than usual, and it was with the greatest difficulty that I managed to get impressions of the dental arches. These showed that the upper incisors were horizontal, the incisal edges being actually above the level of the anterior palatine mucosa. $\underline{6\ 4 \mid 4}$ were inclined buccally so that the occlusal surfaces were facing outwards; the buccal wall of the alveolar process of the maxilla seemed to have given way, allowing the dental arch to expand labially and buccally by a centrifugal movement of the crowns. Spaces had appeared in the incisor and canine regions; the right upper first molar and the upper first premolar were so tipped that the lower teeth occluded on their lingual surfaces. In the lower arch, the right lower lateral incisor had been lost. The intermolar width of the lower arch was excessive, but no buccal inclination of the molars or premolars had taken place. The lower incisors were labially inclined, and there was a slight anterior open bite. The tongue was large and rather red, appeared irritated, and showed lobulations with intervening folds as if it had been forced into a cavity too small to contain it.

Fig. 1.—Maxillary arch before wearing brace and after wearing Milwaukee brace for 3 years 5 months.

A lateral skull radiograph showed a great decrease of the vertical height of the face below the orbits. Both maxilla and mandible were very shallow, the upper incisor crowns were in line with the hard palate, and the roots of the cheek teeth were lying above the level of the nasal floor. The maxillary antrum had little depth, the body of the mandible was extremely shallow, and the apices of the roots of the cheek teeth were apparently in relationship with the lower border. The mandibular incisors were proclined at an angle of 110°. It appeared that there had been a check to the vertical growth of the maxillary and mandibular bodies and the corresponding alveolar processes (*see Fig.* 3). Unfortunately, in this case it was impossible to assess the normal shape of the face as we had no control records. The mother, although

wearing full dentures, showed a tendency to a skeletal Class III facial shape. In March, 1961, the patient was finally taken out of the over the iliac crest. From this ring as the basis rise one anterior and two posterior vertical struts. These are variable in length

A B

Fig. 2.—A, Dentition of child who has worn Milwaukee brace over 9 years; B, Nine months after removal of Milwaukee brace, showing spontaneous rise in bite and repositioning of teeth.

Milwaukee brace, and since then the teeth have tended to become more upright. By October the lower incisors had an angle of 90° to the mandibular bone, and the upper incisors, in becoming more vertical, had become definitely lingual to the lower and taken up the typical Class III reversed overjet. The right upper first molar had so far uprighted itself that its lingual cusps were in lingual relationship with the buccal cusps of its fellow in the opposite jaw. The left upper first molar and both first premolars had swung down so that their occlusal surfaces contacted those of the lower teeth. It would appear that the dento-maxillary structures were assuming their genetic shape. (*Fig.* 2.)

This is probably the most severe case of malocclusion following the use of orthopædic braces that one is ever likely to see. Not only was she under the influences of the braces from the age of 2½ years, but the presence of neuro-fibromatosis, with the accompanying softening of the bone which is characteristic of this disease, added to the flexibility of the arches and to the magnitude of the deformity produced.

It might be time now to consider the Milwaukee brace which had caused these disturbances to dentofacial development. The brace as used in Edinburgh consists essentially of a padded ring fitting round the pelvis and and connect with the head support, which consists of a pad contacting the occipital protuberance at an angle of about 45°, and a

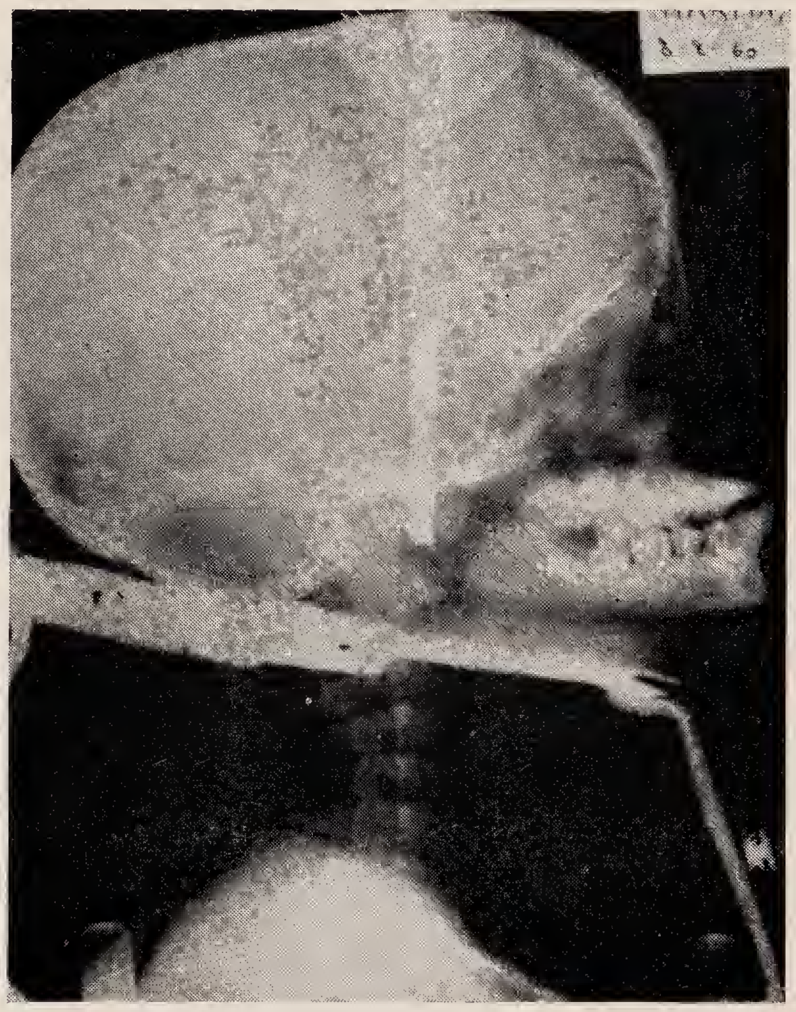


Fig. 3.—Cephalograph of patient in brace showing the effect on dento-facial development of wearing the Milwaukee brace for over 9 years.

horseshoe-shaped pad which is in contact with the lower border of the mandible. Tension is produced by increasing the distance between the pelvic part and the head support, thus

gradually straightening the vertebral column. (*Fig.* 4.) One great advantage of this appliance is that the patient is ambulant. On application of the Milwaukee brace the vertical members

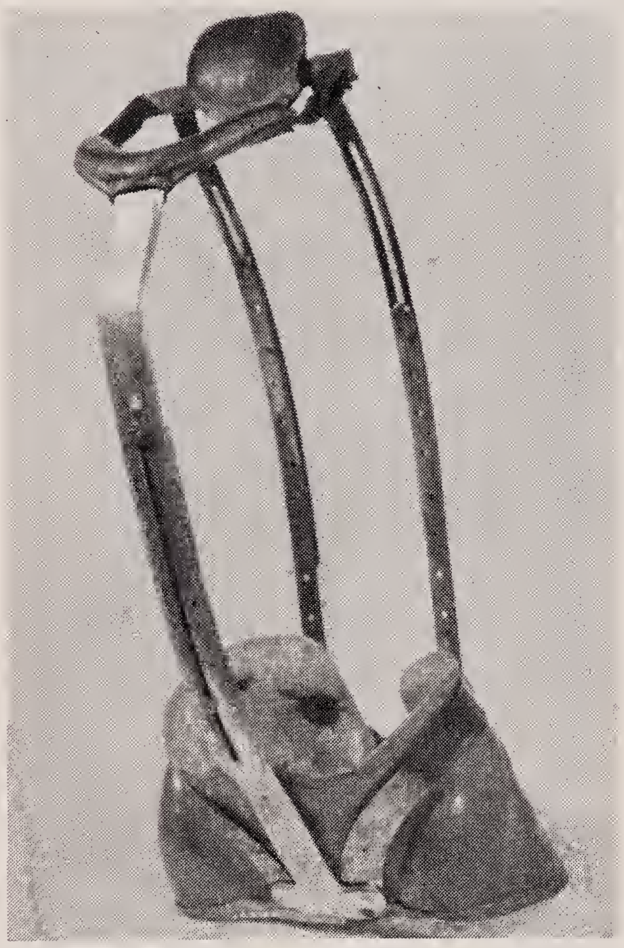


Fig. 4.—Milwaukee brace seen from front.

are so lengthened that the chin-piece just permits the patient to raise his chin about an inch from the pad. This is sufficient to enable him to eat. Within a day or two he may complain of discomfort in the molar teeth or of the skin compressed by the pads on pelvis, occiput, or chin. Usually this soon disappears, but it may be necessary to reduce the tension somewhat. The brace is then adjusted monthly to maintain the pressure as the spinal curve straightens. The brace is worn pre-operatively in order to straighten out the scoliotic curve, and when sufficient reduction is obtained the child is taken into hospital, put under distraction into a plaster jacket, which keeps up the pressure on jaw and occiput, and the spinal fusion operation is carried out. The child continues in the plaster jacket for six months, when the wound is reopened and the area of fusion is inspected for the presence of pseudoarthroses due to incomplete fusion. If present, these are corrected. The plaster jacket is removed and the patient once more put into a Milwaukee brace as a retention for a further six to nine months, until it is seen that the apophyses on the crest of the ilium extend to the region of the posterior superior spine, which, as Risser observed, indicates the cessation of growth in the vertebræ. The Milwaukee brace may be applied earlier if the scoliosis is progressive and is causing difficulty with respiration. In any case, the fusion is not carried out before about 12 years of age.

I was so much impressed, as you may well imagine, by this first case, that I approached Professor J. I. P. James and obtained from him permission to examine every child admitted to the scoliosis clinic and take suitable records before, during, and after treatment. This has been by no means an easy task, but I have been much assisted by my registrar, Mr. Gavin James, and we have now over 50 cases under observation.

It appeared evident to me that here we had a unique opportunity to investigate an artificially produced malocclusion and that this might well give us positive evidence on some of our fundamental orthodontic problems. I decided, therefore, in the first instance, to direct our studies to the examination and definition of the malocclusion produced, to determine the factors which cause the malocclusion, and to leave the question of treatment of the malocclusion entirely alone until the fundamentals were established. Finally, I wish to determine if the process is reversible and if the malocclusion will clear up spontaneously once the brace is removed. This investigation will, of course, take some years to complete, but we have made some progress in the last eighteen months.

The malocclusion produced appears at first sight to consist of a centrifugal spreading of the upper dental arch, the buccal alveolar plate yielding as the teeth tend to spread outwards over the edge of the maxilla. In the lower arch the effect is different. There is a spaced proclination of the lower incisors with a depression of the lower premolars and molars. The lower canines are slightly proclined, but not being depressed come into contact with the palatal mucosa, lingual to the upper canines, where, with progressive deepening of the overbite, they produce characteristic pits in the palatal mucosa. It is

interesting to note that these pits show no signs of mucosal inflammation.

I decided to assess, and, if possible, to measure the amount of pressure produced by the brace. It will be remembered that Blount claimed that the brace produced no actual pressure on the skull, but it seemed to me that there must be some pressure produced, at least sufficient to obliterate the freeway space. I devised a simple apparatus, which consisted of two rigid levers hinged at one end and separated at the other by a spring whose tension could be varied. An electrical contact provided a signal when the levers were touching. The ends of the levers were placed between the molar teeth. The patient was asked to adopt his usual posture, not raising his head out of the brace, and with the molar teeth resting on the levers. Pressure was then built up between the levers by increasing the tension of the spring until the teeth separated. The tension of the spring necessary to separate the teeth when relaxed was taken as being the equivalent of the pressure of the brace. This method did not prove very satisfactory. The levers between the teeth obviously constituted a foreign body of such magnitude as to make complete relaxation difficult. Nevertheless, I obtained some readings of about 4 lb., which rather surprised me, as I had expected a pressure of greater magnitude. We next considered measuring directly on the brace. In a case under distraction, if the locking screws on the anterior stay are released the upper part usually comes down about an inch as the brace collapses. A spring-balance was used to pull the upper part up to its former position, the reading on the spring-balance representing the pressure of the brace on the chin. This method gave consistent results until the third case we tried it on, when we found that on releasing the screws on the anterior stay the upper part rose instead of falling. We realized that the curved back stays must also be taking a part, and to measure the tension of them simultaneously seemed too complicated a procedure. Finally, I invoked the aid of Dr. D. C. Simpson, of the Medical Physics Department, Edinburgh University, who devised for me an apparatus which fitted between the chin pad and the skin, and whose deviation due to the pressure of the brace could be measured by means of a strain gauge (*Fig.* 5). What is more, he made use of a potentiometer recorder which allowed us to obtain a continuous record of the pressure over a period of time in the shape of a graph (*Fig.* 6).

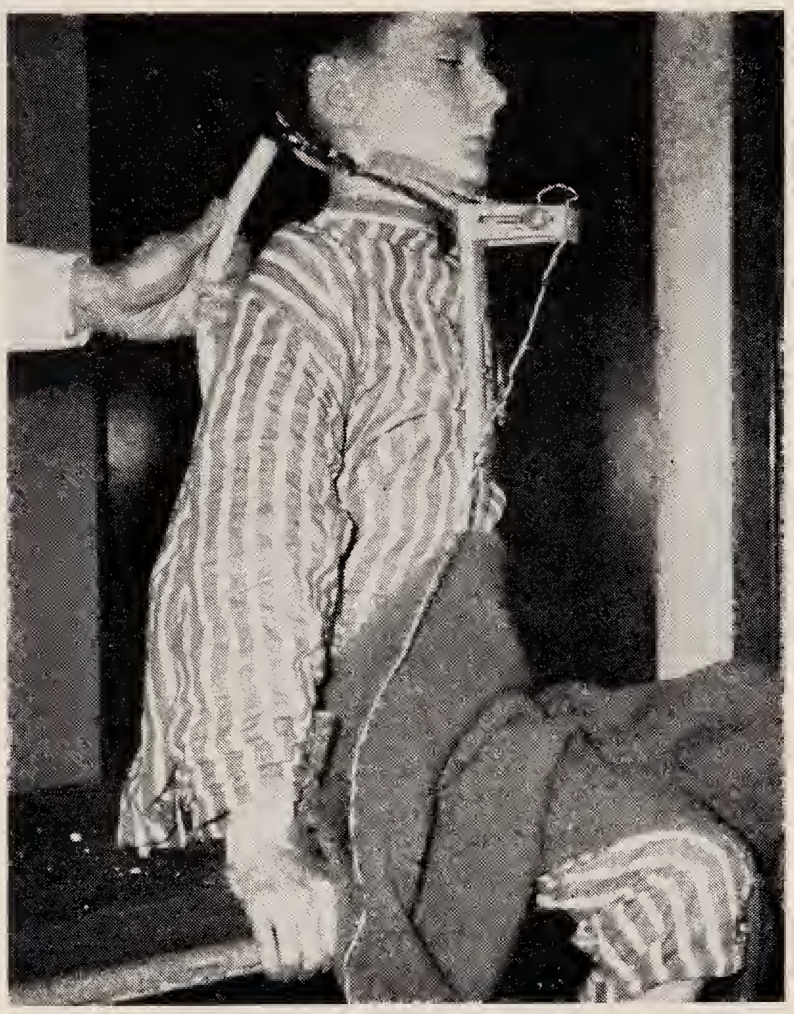


Fig. 5.—Patient in Milwaukee brace, with strain-gauge apparatus giving continuous record of pressure on chin.

We found from these observations that the pressure varied from minute to minute according to the movements and posture of the patient, but it varied within fairly narrow limits, except when the patient was changing his position or moving his head. The graphs tended to show a band of oscillations corresponding in breadth to a variation of from 1 to 3 lb. Peaks of increased or decreased pressure corresponded to changes of position or posture. Of five cases observed, four showed an average pressure of 4 lb. and one of 2 lb. Two showed a momentary maximal pressure of 10 lb., two of 7 lb., and one of 4 lb.

The minimum resting pressure in two cases was 3 lb., in one 2 lb., and in one zero. It was therefore deduced that the first three were usually under pressure, and only the last one was frequently free of pressure on the mandible.

The absolute minimum was a momentary negative peak; one case reached 3 lb., three reached zero. The registration of zero pressure corresponds to Blount's statement that the brace is exerting no forcible traction, and that

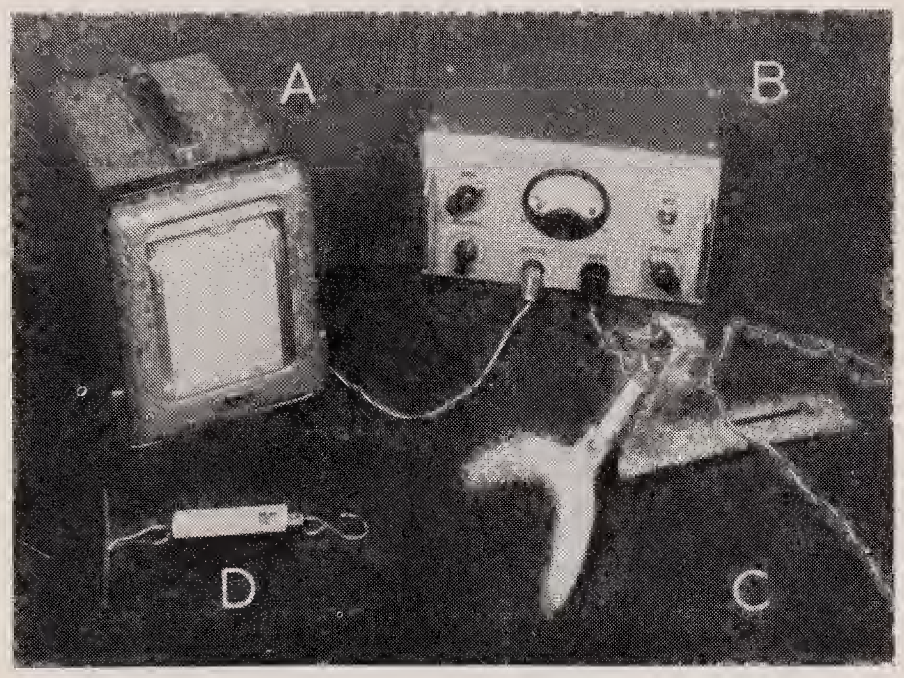


Fig. 6.—Apparatus for continuous recording of pressure of Milwaukee brace. A, Potentiometer recorder; B, Bridge; C, Chin-piece with strain gauge for attachment to Milwaukee brace; D, Spring balance to calibrate strain gauge.

the patient, by his own efforts, is straightening his curvature. This did not occur frequently in this very small and exploratory series, and was only observed momentarily once in 35 minutes in one case, and three times in 15 minutes in another. In the third case minimum resting pressure was zero, with the patient returning to zero pressure every few seconds. This boy was wearing a post-operative Milwaukee brace. He had been only 6 months under the influence of distraction appliances. During this time the curve had been corrected from 30° to 12°, the vertebræ between T.10 and L.4 had been fused, and at the revision 5 months after the operation had shown a solid graft.

His dentition showed no malocclusion other than a rather deep overbite. One would conclude from those few and exploratory observations that an intermittent pressure of an average of 4 lb. is produced on the mandible. The lower dental arch closes up on the upper with obliteration of the freeway space.

There may be some pressure on the soft tissues of the submandibular region, and this, accompanied by the rise of the mandibular muscle attachments consequent on the elevation of the mandible, forces the tongue to the front of the mouth and may account for the centrifugal character of the tooth movements. The pressure on the skin may, if not carefully controlled, cause pressure sores, and is sufficient to cause discomfort both under the mandible and on the occiput. Patients also complain of pain and discomfort in the molar teeth. These symptoms regress as the patient becomes accustomed to the brace or as the tissues affected make adaptive reactions. It would appear that the orthopædic procedures involved in distraction of the spine during the treatment of scoliosis have an effect on the developing dentition.

The effect is greatest when the braces are applied at an early age and have to be worn for many years. The effect is maximal when the bone structure is abnormal, as in neurofibromatosis.

The effect is least when the braces are applied for a short time and when the development of the dentition is complete, or almost complete, apart from the eruption of third molars. The primary effect is a deepening of the bite. This is probably due to sinking of the molars and premolars, and is reversible (*Fig.* 8).

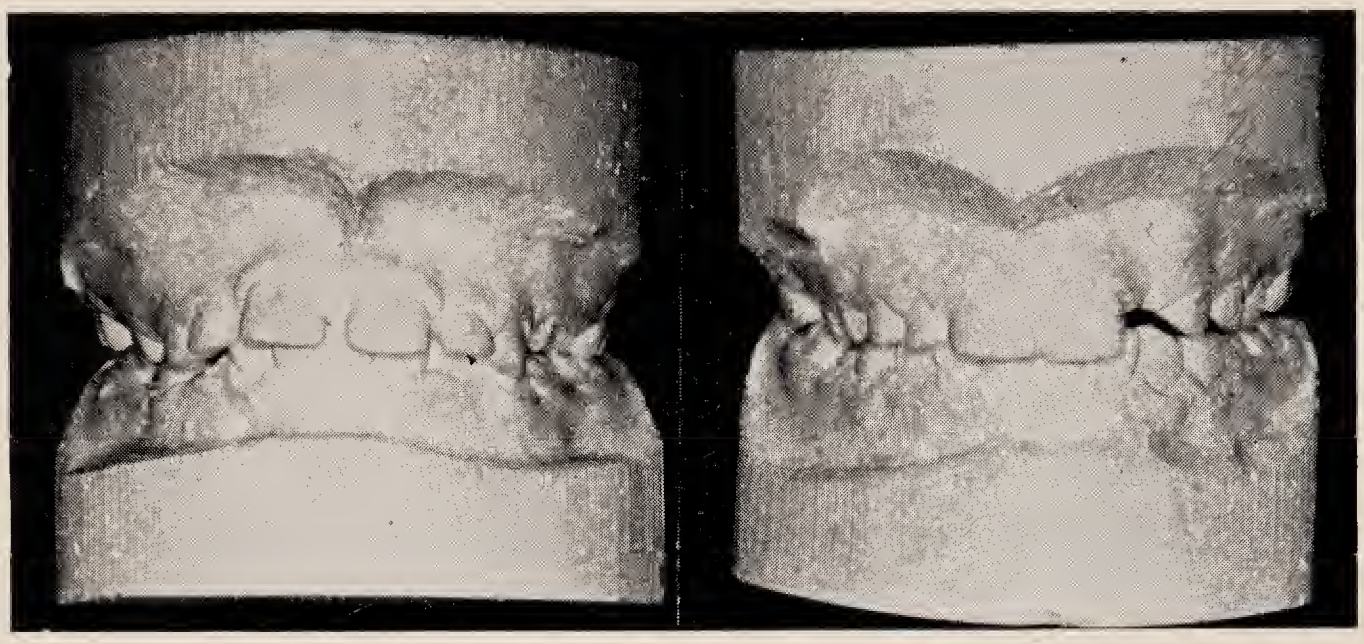
Further effects are proclination and spacing of both upper and lower incisors, with widening of the maxillary arch in the molar and premolar region (*see Fig.* 1). This effect may be enhanced by pressure on the tongue, which shows signs of irritation with the production of folds on its surface. The maxillary canines may show slight proclination and relative lengthening. The lower canines show relative lengthening, with the production of pits on the muco-periosteum of the palate (*Fig.* 7).

Maximal effects show disintegration of the maxillary dental arch. The incisors are proclined above the horizontal, producing an open bite. The posterior teeth of the upper arch are tipped outwards until their occlusal surfaces face the cheek. The lower arch shows little increase in width, but great depression of the molars and premolars. The lower incisors are splayed forwards. All these effects are spontaneously reversible, to what extent I am not at this stage prepared to say.

I have no observations, as yet, to offer on the effect on the shape of the basal bone of the maxilla or mandible nor on the structures of the temporomandibular joint. I have seen no changes in the anteroposterior molar arch relationship. It seems to me probable that the interlocking of the anterolingual cusp of the maxillary first molar with the central pan of the mandibular first molar is enhanced by the pressure of the brace, thus conferring stability in neutro-occlusion.

I would suggest to you that here we stand on the edge of a field of experimental observation of the growth of the dentition and of its supporting structures which will well repay the most careful investigation during the next few years.

Acknowledgements.—I have to record my thanks to Professor J. I. P. James for the opportunity of seeing these cases and for his kind permission to make use of his case records. I am indebted to Professor John Boyes for his encouragement and for the facilities which his photographic department has given me in



A B

Fig. 7.—A, Mixed dentition after 17 months in Milwaukee brace, showing deep overbite and splaying and protrusion of permanent central incisors and deciduous lateral incisors and canines; B, Twelve months after removal of Milwaukee brace, showing spontaneous rise in bite and repositioning of upper incisors and canines with closure of gaps.

A

B

C

Fig. 8.—A, Lingual view of arches of 14-year-old child showing degree of overbite before application of Milwaukee brace; B, After 3 months in brace, showing closure of bite; C, Seven months after removal of brace, showing rise in bite above original level before application of Milwaukee brace.

making many of the slides. My grateful thanks are also due to Dr. D. C. Simpson, of the Medical Physics Department, Edinburgh University, who not only gave me much of his valuable time in devising the strain-gauge apparatus and in having it constructed in his department, but spent many hours with me in clinical observations.

DISCUSSION

The President said that it was not customary to have a discussion following the Presidential Address and that he wished to conform with that custom. If, however, anyone wished to ask a question, he would be very pleased to answer.

Mr. Pringle asked if anyone had tried to design appliances without applying force to the mandible, and, if so, had they had any effect.

The President said that our surgical colleagues used the braces somewhat empirically. It was difficult to envisage another hold on the skull except by using a halo—a circular steel ring with four pins put into the skull. This immobilized the patient.

A paper had been published in Germany the previous year describing a modification to put less pressure on the mandible. It appeared from the pictures that this made little real difference.

Mr. Glass mentioned that he had read a paper on this subject to the European Orthodontic Society in the summer of this year, but it was not yet in print.

He thought the President's approach to this problem of the effect of external pressure on the teeth or jaws was sound, and would, in time, give interesting results, especially as he was seeing all his patients before, during, and following fitting of the Milwaukee brace. He thought, however, that some or all of the cases should be treated to prevent the compression and collapse of the dental arch, and he thought it was particularly important to convince the orthopædic surgeon that the deterioration in the occlusion caused by the external pressure could be prevented in most of the cases.

Finally, Mr. Glass wished to know if the President was doing routine head radiographs at the various stages of the treatment.

The President said that he was very glad to hear there was a paper he had missed; he looked forward to it with the greatest interest.

He was quite clear in his own mind that he would not consider treatment at all until he knew what he was up against.

Mr. J. D. Atherton complimented the President on his very interesting paper. He fully agreed with the President that these cases should not be treated at present. He thought that the facial pattern is a stable one, and following removal of the Milwaukee brace it would return to normal.

He had seen a patient treated with a similar, but possibly more severe brace, which had led to condylar damage and agenesis of that side of the mandible. He would like to ask Dr. Logan whether he had noticed any condylar damage in the patients he had under his care.

The President said the amount of force varied considerably. In Edinburgh patients came to the clinic from the whole of Scotland and the north of England. Adjustments were carried out by their local doctor and sometimes these were too great or too small. He had not examined the mandibular joints, but none, apparently, had anything wrong with them yet. It might be that the hyperplasia in Mr. Atherton's case had been present before the brace was applied. He was taking full records and hoped to be able to answer the question more fully in four years' time.

Mr. D. Greer Walker wished to add his plea that the President did some treatment; he thought at least one case should be treated. There seemed to be a loss of vertical height and a failure of facial growth. One suggestion he would make was that the load should be taken by the incisor or molar teeth only on alternate weeks, the bite being propped open by a suitable splint.

The President said that it was a good thing that he was a strong-minded man, what with the importunities of the parents and children, and now Mr. Greer Walker! But he was quite determined to take no interest in the question of treatment until it was investigated further and he understood what it was he was going to treat. There was a tremendous amount to be learnt in the cases, and he hoped that any members who came in contact with such cases would try to get complete records and study them.

Mr. H. D. Astley Hope asked if he had noted any alterations in the position of the lips or the means by which an anterior oral seal was made, as the proclination of the incisors increased under the pressure of an orthopædic appliance, and whether this affected the self-correction of the abnormality when the appliance had been removed.

The President said that the lips were very tightly closed in all cases; they were everted and compressed by deepening of the bite.

Mr. G. A. James said he had seen cases of children where the lower incisors were so loose that one would consider that there was severe periodontal damage with a real possibility that they would lose them. Putting in a bite plate on top of this might well precipitate this loss, and would be a considerable risk, especially if no other treatment were given.

Miss J. Bradley asked if he had noticed, during the treatment with the Milwaukee brace, whether there had been any absorption of the upper incisors as a result of the splaying out of the teeth.

The President said that no shortening of the roots of the incisors had been noticed.

Mr. J. Beresford said that, some months ago, a very cultured European gentleman had brought his daughter to him for consultation and, after discussion, it was agreed that she should have an appliance. At the next visit, her mother, an American lady, came with her, and as he prepared to fit the orthodontic appliance, she said, "What is that?" He had told her it was an orthodontic appliance. She had said, "I want braces on her teeth!" When he had arrived that evening, he thought the President was going to show him a new appliance for alining teeth; there might be one or two others who felt the same. The truth brought no feeling of disappointment. They looked forward to even more valuable work which it was hoped the President would reveal to them later.

He moved a hearty vote of thanks, which was carried by acclamation.

THE ACCURACY OF TRACINGS FROM CEPHALOMETRIC LATERAL SKULL RADIOGRAPHS

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LARGE-SCALE research is being undertaken in the orthodontic field, and this relies to a considerable extent on the use of tracings from lateral skull radiographs. An investigation into the accuracy of the technique has been undertaken. Two main sources of error exist. The first arises in the taking of the radiograph and results in duplicate radiographs of the same subject not being strictly comparable; the second arises at the tracing stage. Only the second source of error is considered in this paper, the first being subject to further investigation.

RADIOGRAPHIC METHODS AND APPARATUS

The following radiographic technique was used:—

Distance.—The focus–film distance used was 6 ft. The measurement from the sagittal plane to the front of the Potter-Bucky casing was 4 in., and from the sagittal plane to the film, 5 in.

Centring Device.—The X-ray tube and earplugs were alined approximately by means of calibrated scales, and the final adjustment was made by an optical device directed at markers on the craniostat. As a check, radiopaque markers were incorporated in the earplugs; on one a metal ring was fixed, and on the other, a metal spot. When correctly centred, the dot appeared in the centre of the ring on the radiograph.

Craniostat.—The craniostat was attached to a metal bar which was fixed to the floor and the ceiling. The arms for the earplugs were of $\frac{1}{2}$-in. thick perspex, and only the one on the tube side was movable. The earplugs were tapered, with a consequent self-centring action.

Filter.—A wedge-shaped aluminium filter was used to lessen the penetration in the anterior part of the face. This was 8 in. long and 3 in. wide, and the wedge was $\frac{3}{4}$ in. at the thick edge. It was fixed on the tube side of the craniostat at approximately 9 in. from the sagittal plane.

Potter-Bucky Diaphragm.—The movable diaphragm used in this series was the parallel grid type, adjusted according to the time of exposure.

X-ray Tube.—The exposures were made with a rotating anode double focus tube, and a focal spot of 2-mm. size was used.

Films and Intensifying Screens.—"Standard" type films, size 10 in. × 8 in., were employed routinely, in conjunction with "high definition" intensifying screens.

Exposure Factors.—The following exposure factors were adhered to throughout:—

Milliamperage	150
Kilovoltage	80–84
Time	0·4–0·8 sec.

The kilovoltage and time were varied according to the patient's age and size.

TRACINGS

A random selection of 40 radiographs was made, eliminating those in which the permanent incisors had not erupted. The ages of the subjects, who were of both sexes, varied from 8 to 16 years. These radiographs were traced by a professional tracer who marked

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on the tracings: (1) The sella (S); (2) The nasion (N); (3) The point of greatest concavity of the maxilla (A); (4) The point of greatest concavity of the mandible (B); (5) The mandibular plane (M); (6) The Frankfurt plane (F); (7) The planes of the upper and lower incisors (I).

Table I.—Measurements of Seven Angles in Forty Individuals as measured by Tracer A on the First Occasion

	SNA	SNB	FM	I–M	I–F	I–I	I–SN
1	78½	79½	28½	74½	112	143	109
2	77	76½	27	91½	118	123½	110
3	79½	69½	26	88½	119½	124½	106
4	77½	72½	39½	89½	95	137	90½
5	82½	78½	26	86½	100	146	92
6	80	75	33	89	101½	135½	96
7	83	79	26½	104	114	116	108
8	84½	84	35	86	118½	120	120
9	79½	71½	35	89½	110½	124	102½
10	81	77	25	94	97	145½	91½
11	86	80	28½	92½	112	126½	110
12	82½	74½	32	100	117	110	109½
13	70½	68	32½	84½	94½	147	85
14	78½	74½	21	101	95	141	87½
15	80	75½	31	99½	100	130	96½
16	77½	73	33½	99	110½	115½	106½
17	79½	77½	17½	91½	115	135	106
18	75	70	40	82½	85	152½	78½
19	82½	76½	33	89½	91½	146	86½
20	78½	78	40½	66½	110	143	105
21	79	76½	31½	85½	116	127	107½
22	86	75½	36	85	115½	123½	108½
23	78	73	50	81	108	121	110
24	79	72½	31½	89½	118	124	110½
25	79	74½	36	95	105	124½	98½
26	76	74	36	81	102	141½	94½
27	81	82	24	74	108	158	102½
28	75	70	36	97	105½	120½	97½
29	80½	74½	32	94½	110½	123½	104
30	78	71½	40	94	94½	132½	87
31	77	72	30	95½	105	128	97
32	84	79½	29½	84½	90½	154	90
33	80	77	19½	96	104½	139	96
34	80	75	30½	101½	106	119	99
35	78½	76	39	74½	105½	140½	100½
36	87½	78	27	108	94	129	90½
37	81	77½	28½	92½	100	138	96
38	86	80	27	99½	121	112	117
39	78	76	32	86	112½	128½	107½
40	80	76	26½	99	101	131½	86½

From these were determined the angles: SNA, SNB, FM, I–M, I–F, I–I, and I–SN.

The same radiographs were next traced and measured by an independent tracer, and the work was then repeated by the original tracer, who did not know that she had previously handled the same radiographs.

RESULTS

The angles recorded on the three occasions of measurement are shown in *Tables I–III.* Taking first the two series of measurements by tracer A, we can form for any one angle the set of 40 differences between the results on the first and second occasions, and can calculate

Table II.—Measurements of the same Angles in the same Individuals as measured by Tracer B

	SNA	SNB	FM	I–M	I–F	I–I	I–SN
1	77	79	33	67	110	149	107
2	77	75½	29	91	114	127	109
3	78	68	30	83	122	126	108
4	79	73	41	90	90	137	88
5	83	78	34	80	89	155	90
6	82	76	32	92	102	133	108
7	83	77	25	96	114	123	109
8	84	84	34	88	115	123	114½
9	80	72	39	87	105	128	103
10	83	77	31	88	91	148	97
11	88	82	23	100	116	118	112
12	80½	75	33	96	115	115	108
13	70	68	33	85	98	142	90
14	80	76	27	82	101	150	98
15	80	75½	30	95	101	129	97½
16	79	74	34	96½	111	118½	107½
17	78	76	18	88	116	138	105
18	77	70	40	80	91	150	86
19	82	76	31	90	95	143	90½
20	78	78	40	64	107	147	103½
21	79	77	32	81	113	135	106
22	87	75	35	77½	111½	133½	105
23	76½	74	53	76½	103	126½	101
24	73½	71½	34	85½	110	130½	107
25	80	75	30½	97	112	120½	103½
26	75	73½	35	76½	101	146½	96
27	82	81½	20½	72	110	155	107½
28	77	71	35½	92	105	126½	99
29	81	74	34½	89	104½	131½	102
30	79½	72	38	94	87	138	82
31	75	70	29	92	103	135	95
32	83	78	31½	85	87½	155	88
33	79½	77	19	96	105½	138½	96½
34	83	79½	30	109	104	117	105
35	80	78	38½	72	104	145	101
36	89	78	24		92		90
37	80½	76½	28½	91	99	140½	95½
38	86	79½	27½	98	107	125	103½
39	80	77	34½	88	114	124	113
40	80	75½	30	94	98½	137½	94

the mean and standard deviations of these differences (having regard to their signs). The results of this calculation for all seven angles are shown in the first part of *Table IV.*

The interpretation of these figures is quite straightforward. Denoting the mean by m and the standard deviation by s, we can say that

in a long series of duplicate measurements, some 68 per cent of all differences would be expected to lie in the range $(m - s)$ to $(m + s)$, while 95 per cent would be expected to lie in the range $(m - 2s)$ to $(m + 2s)$.

Since the same angle is being measured on each occasion, we expect the mean difference to be close to zero. It is easy to test whether the observed set of differences for a particular angle shows a bias in one direction or the other, and the results of such a test are indicated in *Table IV* by means of a system of symbols. A single asterisk indicates that the probability of such a large average deviation from zero arising from chance alone is less than 5 per cent, while other symbols correspond to probabilities of less than 1 per cent and less than 0·1 per cent respectively.

Table III.—Measurement of the same Angles in the same Individuals as measured by Tracer A on a Second Occasion

	SNA	SNB	FM	I–M	I–F	I–I	I–SN
1	78½	77½	28½	69	113	149	106½
2	76½	76	27½	92½	119	121½	110½
3	77½	70	29½	87	114½	129	102½
4	77½	72½	39½	90	92½	138½	87½
5	82½	79	28½	84	100	149	91½
6	80	75	30½	88	104½	137	95½
7	83½	78½	27	103½	111½	118	107½
8	83½	82½	36	89½	117½	116½	119
9	79	71½	39½	89½	105½	125	101½
10	80½	76	19	95½	92	142½	91½
11	86½	80	25½	92½	109½	126½	109½
12	82½	75	31	96½	120½	112	111½
13	70	67½	30½	88	97	144½	84
14	78½	74½	27½	95	89	148½	86½
15	85½	78½	30½	102	97	130	95
16	77½	73½	33	98	112	117	107
17	79½	77½	19	93	115½	132½	107
18	75	70	41	77	85	157	79
19	82½	76	36	91	89	145	87
20	76½	75½	38½	62	111½	148	104½
21	79½	76½	34	81½	114	130½	108½
22	85½	76½	34½	82	114½	129	107½
23	76	71½	51½	74½	108½	126	99½
24	79	71½	33½	88	112	126	108½
25	79½	75	38½	96½	102½	122	99½
26	77	74½	37½	81½	103	138½	97
27	80½	82½	19	75	105½	159½	100
28	75½	70	40½	92½	105	126	96½
29	79½	74½	32½	89½	110½	127	105
30	78	71	41½	92	93½	132½	88
31	78½	73½	27½	97	103	132	96
32	82½	78	29	85½	96	149½	91½
33	80	76½	18½	97½	108	136	96
34	80	75½	29½	102½	107	121½	99½
35	77½	76	39½	76	103	141	98½
36	87½	78½	26½	106½	96	130½	93½
37	81	77½	30	90½	102	137½	78½
38	86	79	26½	102	124	114	119
39	79½	78	33½	86½	110	129	109½
40	78½	74½	30	99½	97½	132	94

The second half of *Table IV* gives similar results derived from differences between tracer B and the average of tracer A's two measurements. The standard deviations have been adjusted so that they relate to differences between single measurements by the two tracers.

Table IV.—Means and Standard Deviations (in Degrees) of Differences between successive Measurements by the same Observer and by different Observers

	One Observer		Two Observers	
	Difference (A_1–A_2)	Standard Deviation	Difference (A–B)	Standard Deviation
SNA	+0·1	1·22	−0·2	1·91
SNB	+0·2	1·05	−0·1	1·44
FML	−0·8	2·94	−0·3	3·38
I–M	+1·1	3·14	+2·4‡	4·33
I–F	+0·8	2·91	+1·3	5·47
I–I	−1·2*	2·99	−2·6†	4·47
I–SN	+0·6	3·14	−1·0	5·54

Symbols denote mean differences significantly different from zero (*P<5%; †P<1%; ‡P<0·1%).

DISCUSSION

Inspection of the *means* in *Table IV* shows that the angle of the lower incisor to the mandibular plane and the angle between the incisors are particularly difficult to measure consistently. There are definite differences between tracers A and B, amounting to more than 2° on an average, and there are even consistent differences between tracer A's two occasions of measurement.

Taking next the *standard deviations* for duplicate readings by tracer A, those for the angles SNA and SNB are just over 1°. Discrepancies as large as 2° in these measurements will, therefore, occur fairly seldom. The other standard deviations are all about 3°. This implies that discrepancies of 6° and over will be rare; on the other hand, discrepancies of up to 3° must be expected in nearly 70 per cent of all cases.

As might be expected, the standard deviations are usually increased when the findings

of two different observers are compared. This is particularly so for the angles I–F and I–SN, where discrepancies as large as 10° must be expected in 1 out of every 20 cases.

Means of improving the accuracy can be considered at both the tracing and the radiographic stages. During tracing, it seems essential to use more easily discernible points of measurement. For comparative purposes, all measurements should be carried out by a single tracer, and any conclusions must take into account the limited accuracy of the technique.

With regard to radiographic methods, the focus–film distance used in this investigation was 6 ft. An increase of perhaps 3 ft. might improve the definition, but would necessitate an increase of more than double the exposure, which is not acceptable. A decrease in the distance between the sagittal plane and the film could also improve the definition.

It was thought that the incisors could be traced more accurately if the outline of these teeth could be distinguished more clearly on the radiographs, and, with this in mind, an attempt was made to adapt thin lead foil to the crowns of the upper and lower right centrals. However, close adaptation proved to be difficult and no increase in accuracy was obtained.

In tracing, the recognition of the anatomical landmarks in the radiographs is a very real difficulty. An improvement in the range of contrast in the radiographs might have been of assistance in identifying structures. Contrast can be increased by coning down the X-ray beam and by altering the kilovoltage. However, the beam which was used allowed only a small margin beyond the edge of the film, and there is, of course, a limit to the amount that the beam can be collimated if it is to cover all the necessary structures. Decreasing the kilovoltage could improve contrast, but the necessity of adequate penetration must always be borne in mind. Increased contrast could also be obtained by using a higher ratio grid or a cross-grid, but it is felt that additional exposure would not be justified.

Advantages might be derived from the use of a higher kilovoltage, with the resultant greater penetrating power of the X-ray beam, but the minimization of scattered radiation would present considerable difficulty.

SUMMARY

Lateral skull X-rays on 40 subjects were traced twice by one tracer and once by a second tracer. Seven angles were measured on each tracing. The standard deviation of differences between successive measurements of the same angle varied from 1·05° to 3·14° for a single tracer and from 1·44° to 5·54° for different tracers. Angles involving the planes of the incisors had the largest measuring errors, and were also liable to consistent differences between successive occasions of measurement. Some possible means of improving the accuracy of these measurements are briefly discussed.

DISCUSSION

The President said that members were very indebted indeed to Mr. Broadway for his paper.

At one time he was very interested in the science of gunnery. The distance on the map, strangely, did not measure the same from one day to another. One had to measure how much the map had swollen due to humidity during the night. He often wondered about the question of tracings: they seemed to him to be liable to quite big errors.

As an old gunner, he asked Mr. Broadway to take note of the fact that one did not divide angles into decimal points; one divided them into seconds!

Mr. Broadway had shown by repeated tracings that there was more error than they had thought. He had said he could get a 3 per cent error in 60 per cent of the cases. A 3 per cent error on a long arm of an angle can amount to a considerable number of millimetres. The real fun would start when Mr. Broadway took the same patient and put him back into the cephalostat and took another exposure, then turned his teams of tracers on to it again.

The Frankfurt plane, of course, was devised by Martin, who used it for orienting dried skulls and it was never meant as a means of measuring the skull through the soft tissues. That largely accounted for the difficulties in using it; it was really a cephalological plane.

Mr. G. C. Dickson, opening the discussion, thanked Mr. Broadway for his paper, which consisted of two parts—the account of the technique and the statistical results.

On the technique he had only one observation to make, and that was that he felt that the insertion of intensifying screens to shorten the exposure did a good deal to nullify the effect of the Potter-Bucky diaphragm. Provided that the dosage to the patient was not considered excessive, the best way to get increased definition was to eliminate the intensifying screens and use a fine grain-film.

Increasing the kilovoltage made a much more acceptable film in that it showed the soft tissues more clearly and gave a smaller range of contrast. In the main the points which became indistinct as a result of this technique were the ones which Mr. Broadway had, in his paper, shown to be unreliable anyway.

On the question of the statistics he was not at all happy about the figures given. The mean value for the differences was difficult to understand, as the arithmetic mean (the only one appropriate in this case) was several times larger than the figure given. The "differences" themselves must have a positive value, as no significance could be attached to a second observation being larger or smaller than the first. In Mr. Broadway's tables this was accepted. It seemed rather strange, therefore, that some of his "means" had acquired *negative* values.

Mr. Dickson had, due to Mr. Broadway's kindness in letting him have the paper some three weeks in advance, been able to study the figures in some detail. One finding he thought was of interest was that angle ANB (i.e., the difference between SNA and SNB) on which a good deal of reliance was placed was, in fact, far and away the most accurate angle of all. In 20 observations the mean was 0·5° and standard deviation 0·88°. In fact 18 out of 20 duplicate observations had a difference of 1° or less.

Construction of a frequency distribution table showed 14 values that were sufficiently far from the expected distribution of results as to be worth investigation. Of these, 3 results were due to wide errors in measurement of the upper incisors, and 3 to wide errors of measurement in both upper and lower incisors. Three must have been attributable to poor X-rays, as very few of the angles seem to bear any relation to each other. Two were due to arithmetical errors. In 2 of them the decimal point had been misplaced and in 1 the protractor had been misread (as shown by the fact that the angles between the Frankfurt and mandibular planes and upper and lower incisors formed the internal angles of a quadrilateral, which *should* add up to 360°). It seemed to him, therefore, that in making any cephalometric assessment, the observations should be repeated to eliminate this sort of error, and if a wide variance was observed that they should be repeated the third time.

Mr. Dickson felt that Mr. Broadway's paper was extremely timely and pointed a way to a method of assessment which should be made individually by everybody using cephalometric films in order that they all may have some standard of accuracy, without which their observations must have very little value.

Mr. H. L. Leech asked if it was right to assume that tracer A, who was a specialist tracer, was not an orthodontist. Was tracer B an orthodontist? It is unlikely that a tracer who was not an orthodontist would know what angles to expect, whereas everyone knew that a tracer who was an orthodontist was likely to fiddle his angles to those he would expect!

Mr. A. J. Walpole Day said that on the lateral skull X-ray, one orbit always appeared larger than the other; it was difficult to decide which was the orbital point. Normally, it was taken from the larger orbit. Even that was difficult to determine because the farther-away orbit was lower down than that nearest the machine.

Mr. Broadway had suggested putting in a wedge of aluminium to filter out some of the rays to show the soft tissues. They had placed a little piece of brass plate, about six gauge, over part of the orifice of the tube for the same purpose. After a little experiment this had worked excellently.

The President said that it must not be forgotten that when Martin postulated the Frankfurt plane, he realized that the two orbital points would not lie on a plane, and laid down that it was the lowest point of the left orbit that was taken for the orbital plane.

Mr. P. N. Horswill asked if the radiopacity of the incisors could be increased and highlighted by a mixture of clear nail varnish and lipiodol.

Professor G. E. M. Hallett said that Mr. Leech's point was a very true one; orthodontists tended to read into tracings what they were looking for, but these human errors had to be reduced to the minimum possible.

Cephalometrics carried with it essential imperfections. However thin the film carrier, the structure of the head kept the sagittal plane about $3\frac{1}{2}$ in. away from the nearest point on the film. In trying to project departures from the sagittal plane on to a flat surface, errors would be involved. If the head were perfectly symmetrical, and if each first permanent molar were an equal distance from the central ray, on the film one molar would necessarily be 1 mm. in advance of its fellow on the other side. Unless markers were used it was very easily possible to confuse the medial and distal surfaces of the molar on each side and make a considerable error.

Mr. Broadway had rightly stressed the difficulties implicit in shooting the central ray through a bunched-up collection of incisors and then trying to select, amongst the shadows, the tooth one thought would be the marker for a set of reference points and angles.

It was interesting to take a lateral skull radiograph where there was a root filling in progress, put in a straight wire up to the apex and check it again, and see whether the long axis corresponded with the one traced.

The error would be that much greater in the incisor region than in the molar region, so that when radiographing the dento-facial complex, the central ray should probably be thrown somewhere through the centre; say the first permanent molar instead of porion. One would then have to have a complete set of other reference points and planes—and there were enough already. It could be determined which was the right and left orbit if one understood the principle that the side farthest from the screen would be larger than the side nearest the screen. They must not get too accustomed to relying on skilled tracers. Perhaps the orthodontist himself should trace 1 in 20 of those traced by the skilled non-dental tracers.

Mr. A. J. P. Cousins asked whether the accuracy varied with the age of the patient. What did Mr. Broadway consider to be the lowest practicable age at which reliable cephalometric films might be taken?

Mr. E. K. Breakspear asked whether the differences between the two observers were in any way predictable. Had Mr. Broadway found that observer A would consistently tend to draw his incisors in one particular way, whereas observer B would consistently tend to draw them in another, so that it could be predicted?

Mr. J. C. Ritchie congratulated Mr. Broadway. For him, personally, it was very nice to know the error of his ways. He was reminded of the famous orthodontist who assured him that he never used anything but lateral skull radiographs for diagnostic purposes.

Mr. N. F. Clarke said that apart from the inaccuracies of the tracing of lateral skull X-rays and the obvious two-dimensional limitation, it would seem that there was no standard method of registering the bite. The mandible could not really be related to the maxilla by the Frankfurt–mandibular-plane angle because there

was no guarantee that the patient had been in centric occlusion or in the rest position.

Mr. E. S. Broadway said that when he was asked to give the paper, he expected to be shot at a bit, but he had not realized that the President was a gunner.

Mr. Dickson's idea for getting a better film by using high-definition films and eliminating intensifying screens was worth while taking up. He himself was not an expert radiologist and could not really go into it in any detail, but from what Mr. Dickson had said, it seemed to be a very sensible thing to do.

He too had found that the SNA/SNB angles were remarkably consistent. It was pretty easy to see why. Those points were the points which were the easiest to see on the film. If they were easy to see, they were easy to trace, and if they were easy to trace, it was much easier to be accurate.

Mr. Leech had asked whether tracer A was an orthodontist; she was not. She was employed to do nothing but trace lateral skull X-rays, but she had had a great deal of practice and was quite well aware of the points to look for. He hoped that tracer B was an orthodontist—he had done the tracings himself.

With regard to the orbits being asymmetrical, that was partly overcome by averaging out the two shadows on the X-ray film, but, again, it was guesswork, and meant that, if two people were doing the tracings, one might guess consistently one place and one might guess consistently another place on the film, or both might vary. From his figures, he found that there was no real consistency of guesswork on those points, especially guessing the angle of the lower incisors.

Aluminium filters could be built up by layers of aluminium sheet, either stuck together with "Araldite" or riveted together. The X-ray Department at Ipswich did not use a filter at all. They reduced the film with reducing solution over the area required, which produced a reasonable picture of the soft tissues.

Professor Hallett asked about the difficulties with crowded incisors. It was extremely difficult to trace incisors where there was crowding, even if one had a reference model available and could compare the reference model with the radiograph. He had had the opportunity of examining lateral skull X-rays where dead teeth had been present and one could be very surprised at the angle taken by the root filling compared with the crown; there were quite surprising differences between the angle of the crown and the angle of the root.

He did not think it really made any difference at what age the lateral skull X-rays were taken except that, in the mixed dentition stage, it was almost impossible to trace in the teeth. One could trace in the A point and the B point fairly easily, and the S and N points fairly easily, though the older the patient, the easier it was to see the nasion.

The radiographer who took one's lateral skull X-ray could ruin one's investigation if she did not realize what the rest position was, what the centric occlusion was, or what the protrusive bite was. Few radiographers realized that. He had reached the conclusion that if one wanted accurate lateral skull X-rays with accurate tracings, one had to do the lot oneself; and if one wanted to compare two lateral skull X-rays on different occasions, there was a tremendous number of different factors that had to be borne in mind. First of all, the film used had to be the same; the tube preferably should be roughly the same age; tube performance fell off over the number of exposures used; the temperature of the developer had to be the same. There were many different variable factors. If one was going to be scientifically accurate, one ought to have the same radiographer on the two occasions. All those factors could make a slight difference, and if they all happened to be different, the result could be that the errors were increased. In practice, of course, a large number of the results cancelled themselves out and the technique in general use was an adequate one.

REMOVABLE APPLIANCE TECHNIQUE

THE APPLICATION OF RAPID COLD-CURE ACRYLIC RESIN

By A. J. P. COUSINS, L.D.S. R.C.S., D.D.O., R.F.P.S., *Cardiff*

HISTORY

When first introduced to the profession approximately ten years ago, the major indication for cold-cure acrylic resin was in denture repair work because it avoided flasking and polymerized rapidly without pressure and at room temperature, but it was accepted only slowly in this field because of defects which were chiefly due to unavoidable porosity. In orthodontic appliance construction this defect was not so important, and the material was found to be of considerable utility in alterations and additions to appliances, as well as in their repair. Whether flasked or unflasked, an absence of dimensional change, when compared with heat-cure techniques, was a very marked feature and led to the construction of the whole acrylic base in this repair material. The non-flasking technique has proved to be so successful over the past seven years that it is now being used for all removable appliances.

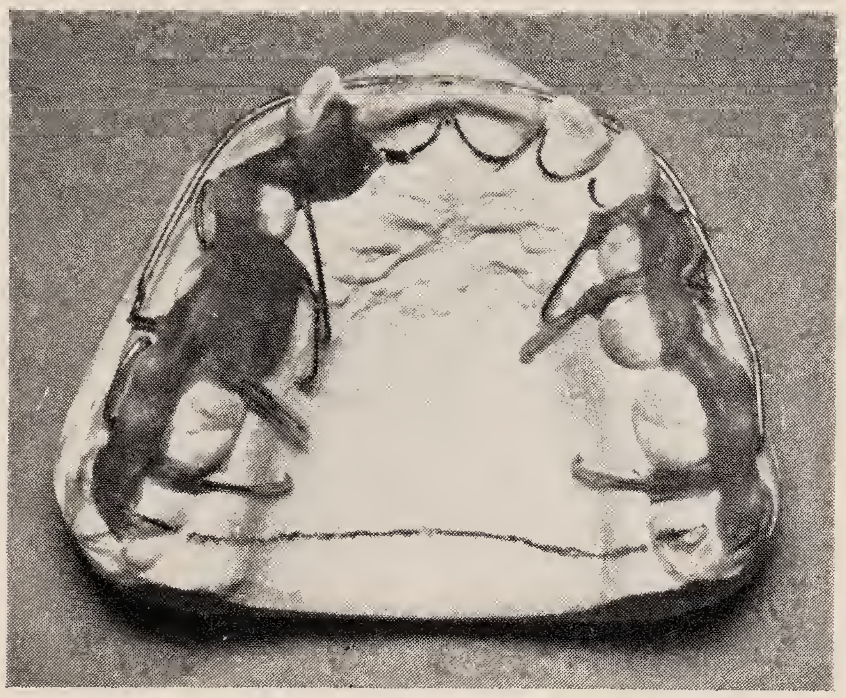

Fig. 1.—Model "waxed up" for application of resin. Note the use of wax rather than plaster-of-Paris for limiting the flow of resin.

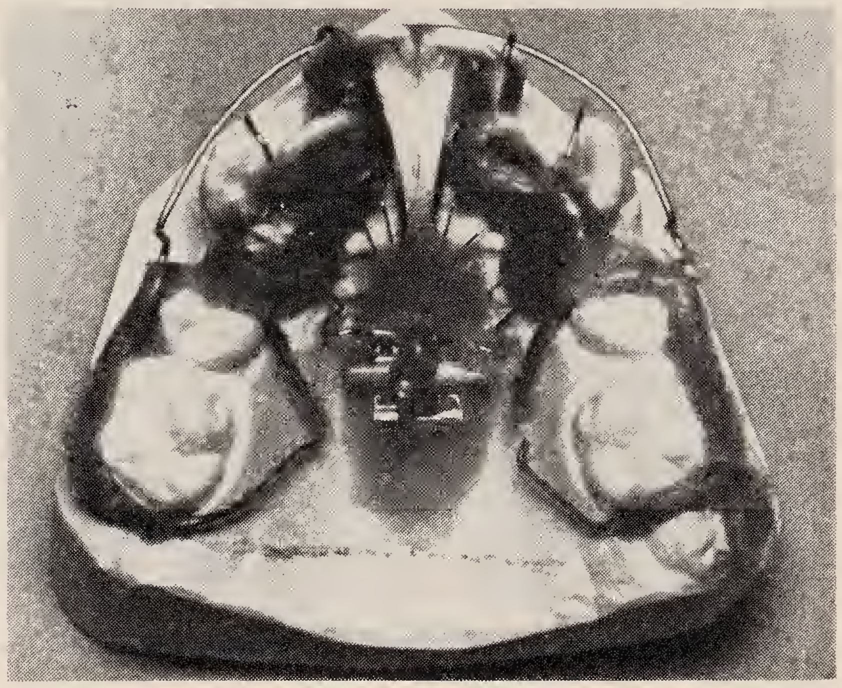

Fig. 2.—Model "waxed up", as in *Fig.* 1, but with an expansion screw already secured in position by a small preparatory mix of resin.

NON-FLASKING TECHNIQUE (LABORATORY)

When cast and dry, the model is coated with a separating medium, and cribs and springs are fabricated in the usual manner. No wax base-plate is prepared, but the free ends of the cribs and springs are invested in wax instead of in plaster-of-Paris (*Fig.* 1). A wax margin may also be added to make it easier to limit the flow of resin. Undercuts too, and any other necessary areas, are blocked out in wax.

The cold-cure acrylic resin is mixed to a fluid consistency and poured with a spatula on to the prepared surface of the model, the flow and thickness of the material being controlled by a combination of gravity, vibration, and digital pressure.

The production of an even thickness requires considerable experience, but a full palate can be produced in one or two mixes, depending on the shape and size of the case, with a further mix for the addition of occlusal cover and bite platform. If an expansion screw is to be used, it is secured first by a small separate mix of resin, wax again being used to block out the free areas (*Fig.* 2). The setting time depends on the consistency of the mix, and on the temperature; the application of dry heat increases the surface porosity, but the use

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of a water-bath, set at 130° F. (50° C.), avoids this effect and reduces the time by about 50 per cent.

TECHNIQUE (CHAIRSIDE)

The adjustment of occlusal cover, with or without bite platform, is carried out by initial spot-grinding in the orthodox manner until the desired interocclusal dimension is obtained. To

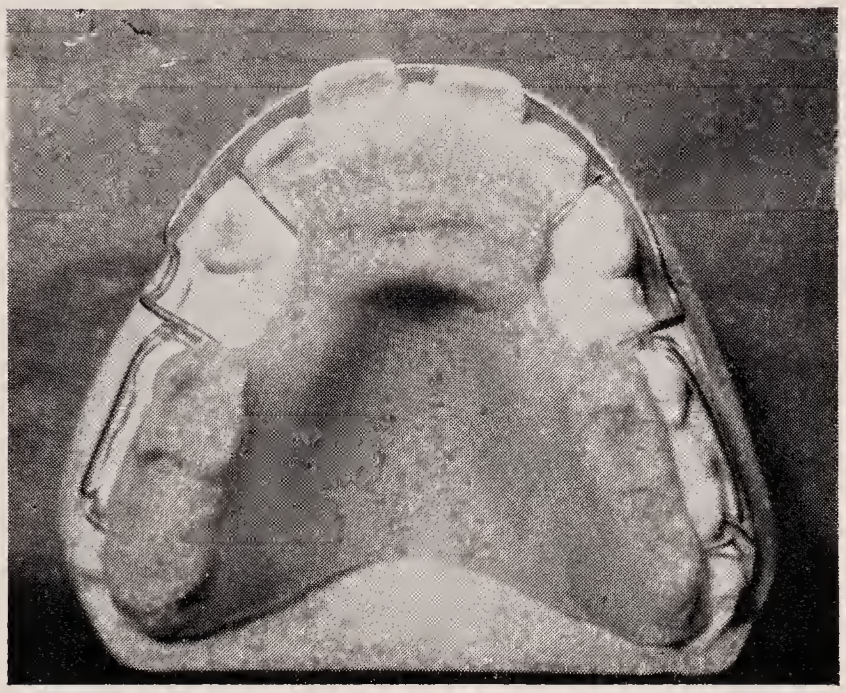

Fig. 3.—Acrylic base showing the indentation made in soft resin by intra-oral contact with opposing teeth.

ensure a completely balanced occlusal contact, and to reinforce the cover, or to provide positive cuspal guidance, an additional layer of resin is applied to the biting surfaces; then the appliance is reinserted in the mouth and the patient is instructed to close while the resin is still soft (*Fig.* 3). Very accurate registration of the bite is obtained, and care is required to avoid lateral or protrusive deviation on closure.

Subsequent trimming will determine the amount of excursion possible, or to be permitted.

CLINICAL INDICATIONS

1. Fit.—A greater accuracy of fit is generally conceded with cold-cure resin, and this is in no way affected by the number of repairs, additions, or alterations made. The non-destruction of the appliance model contributes appreciably to this factor.

Duplicate appliances can be readily produced from the original cast.

2. Anchorage.—Increased anchorage is obtained (*a*) by the better fit of the acrylic base; (*b*) by the increased resistance to tipping of cribbed teeth, retention being three-dimensional rather than two-dimensional when occlusal cover is used: with a multiple crib (*Fig.* 3) resistance to tipping is even greater, and bodily movement only is possible; and (*c*) by the increased facility with which positive occlusal contact can be built up. This enhances the approximation of the base material to the supporting structures, and provides increased resistance to displacement on occlusal contact. It can also give a useful measure of inter-maxillary anchorage without the trauma involved in the use of an inclined plane, and can be used to correct abnormal paths of closure or to provide control of the vertical dimension, with consequent benefit to temporomandibular joint disturbances (Wilson, 1956; Berry, 1959).

3. Dimension.—The simplicity with which the bite can be "raised", without on the one hand exceeding the freeway space or on the other being too fragile, gives a much greater freedom in design, especially of cribs on anterior teeth, and this in turn improves the anchorage, comfort, and efficiency of the removable appliance.

CONTRA-INDICATIONS

1. Porosity.—While this factor cannot be completely overcome without flasking, and would constitute an æsthetic defect in the provision of a denture other than a temporary one, it is of little or no consequence in an orthodontic appliance which has a relatively short life.

Porosity is much more noticeable in a clear resin, and so a tinted base is to be preferred on this account and will also give a better visual contrast with the use of blue articulating paper. The necessity to locate pressure spots in the mucosa with the appliance in position, which is possible with a clear resin, does not arise because of the improved fit obtained with the present technique. Hygiene is affected to some extent by surface porosity, but in practice the difference is negligible, apart from tobacco staining.

2. Taste.—The use of incompletely cured resin in the mouth is unpleasant to some persons, but is very transitory and causes much less disturbance than the taking of the impression.

3. Allergy.—None has been recorded in some 3000 cases over a period of seven years.

Acknowledgement.—I am indebted to Mr. J. L. Taylor for the considerable laboratory work involved in the development and application of this technique.

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DISCUSSION

The President said that all those present would agree that they were very indebted to Mr. Cousins for his intensely interesting paper on the use of quick-setting acrylic. He himself had been very much impressed by the weight Mr. Cousins had given to the question of balanced occlusal pressure, which was important and sometimes forgotten. He was interested also in how Mr. Cousins managed to reinforce his intermaxillary anchorage by use of the impressions on the acrylic. He was rather frightened of getting irritation from free monomer, but Mr. Cousins had had no trouble in that way at all.

Mr. P. H. Burke asked whether Mr. Cousins had investigated the matter from the point of view of costing. On a time basis, was the method to be preferred to the normal method of producing removable appliances?

The President said he was not sure whether Mr. Cousins polished the appliances or whether he was able to take them straight off the model and put them in the mouth. Did he polish the palatal surface?

Mr. Cousins, in reply, said that, as far as costing was concerned, there was considerable advantage. The material was a negligible item. The main cost in producing appliances was in the technician's time involved. On the average, it was about half, so, for the base-plate part, it enabled one technician to do the work of two.

With regard to polishing, the appliances were trimmed and finished in the ordinary way. It was possible sometimes to get very smooth matt surfaces without polishing if one had got the consistency just right, but that was not so easy to do. The material polished to quite a high extent.

MANDIBULAR POSTURE AND DISPLACEMENT

By PETER BLYTH, L.D.S., D.Orth. R.C.S.

The main precept on which this thesis is based is that the development of occlusion is not conditioned at all, or at least only to a minor degree in the later stages of development, by mechanical factors, but that it is related solely to the muscular environment of the teeth. In a previous paper on speech (Blyth, 1959a, b) I tried to show that speech was a late activity that was developed on an existing framework of muscles, bone, and teeth. It was found that the skeletal relationship and the position of the teeth were not, as far as we were able to determine, factors in the causation of a lisp; however, there was found to be a relationship between the lisp and certain types of atypical tongue behaviour. Where such tongue behaviour improved—and cases were shown demonstrating that some types of atypical tongue behaviour could improve—there was a concomitant improvement in the speech. Where, then, the speech was added to an already unfavourable background, it could well be faulty *by virtue of the faulty foundation.*

I want, if possible, to paint a similar picture regarding the development of an occlusion. Apart from the skeletal and local abnormalities, I want to put forward the view that it is the muscular environment of the teeth which produces the final occlusion; and that atypical patterns of behaviour and muscle activity are the cause of certain malocclusions, and not the result of those malocclusions. This is not a new concept when it is related to abnormal tongue behaviour in an anteroposterior direction. Many workers have shown that certain types of Angle Class II, division 1 incisor relationship with open bite are the result of tongue-thrusting swallows.

It is generally accepted that teeth erupt into a field of musculature and that the final occlusion of the teeth is achieved by cuspal guidance.

The main work on which this paper is based is a study of mandibular displacement and posture, and it will be necessary to re-define terms which may be in common use as we go along in order to make abundantly clear exactly what is meant by such terms.

I am convinced that in many cases a mandibular displacement does not exist until we ourselves find it—and by "mandibular displacement" I mean a deviation of the mandible from what we fondly imagine to be a normal path of closure of the mandible. Before elaborating further on the path of closure, I want to emphasize that the sequence of events—initial contact→mandibular displacement→full cuspal occlusion—just does not take place. One is, of course, aware of the concept of reflex avoiding activity on the part of the muscles to avoid trauma, but this still presupposes that the cause of the so-called displacement is an initial contact—a tooth erupting into an untenable occlusal position. The point to be stressed is that at the time when the occlusion develops the initial contact does not exist; it does not exist because the mandible is not held in centric relation. I believe that we have got to visualize the occlusion developing around a functional relationship of the mandible to maxilla, conditioned not by the mechanical dictates of the temporomandibular joints, but solely by the muscular environment. I further believe that this functional relationship may at times be very different from what is known as "centric relationship". We envisage a position of centric relationship when the mandible is normally related to the maxilla with the condyles in their retruded position in the glenoid fossæ. Centric relationship does not exist if the mandible is held forward of this position, or to one side or the other. It follows that if the mandible is held forward or to one side or the other of true centric relation, then one or both of the mandibular condyles are placed in a forward position. It is probable that in the case of a unilateral

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forward position of one condyle the mandible has rotated slightly to produce an apparently distal position of the other condyle. Centric occlusion is defined as the position of the teeth with the jaws closed and the teeth at maximum cuspal occlusion with the mandible in its centric relation. I would like you to visualize also a path or line of centric relation, which is in effect what we assume to be a normal path of closure. But I want, in order to avoid misunderstanding, to define this path without bringing the rest position into the definition. The path of centric relation is the path along which the mandible would normally be expected to open and close from the position of centric occlusion.

Putting all this another way, it is possible to have an asymmetrical or postured muscular environment, which is not necessarily permanent, into which the teeth are going to erupt to the position of maximum cuspal occlusion. The fact that this is not centric occlusion is at the moment of secondary importance. Further, this postured muscular environment may at times be perpetuated or even initiated by certain local habits, such as thumb- or finger-sucking or nail-biting, and these habits may serve as reinforcing stimuli in a conditioned reflex arc. It is not felt that these habits, if present, are causing the malocclusion; merely that they may possibly act as a very small link in a very large reflex chain which is helping to maintain the mandible in a postured position.

Evidence exists to show that it is possible for this postured muscular environment to change at any stage during the full development of the occlusion and return the mandible either part or all the way back to full centric relation, and that this reversion need not be precipitated by any form of treatment.

It may be well to elaborate for the moment on the muscular environment that has been discussed. I am thinking here of the muscles that clothe the maxilla and mandible, of the muscles that go to form the cheeks, the lips, and the tongue, and of their covering mucous membranes. We are accustomed to thinking that the posture of the mandible is maintained by the reciprocal co-ordination of the muscles of mastication and the depressor muscles, and that these combine to produce a position of balance with the teeth out of occlusion known to us all as the "rest position". It seems to me that what may also influence the position of the mandible in space is the position of the tongue in relation to its own surroundings—the lips, cheeks, teeth, and soft palate. As well as proprioceptive nerve-endings in the muscles and periodontal membranes, it would appear that sensory contact between the mucosal surfaces could, by reflex activity, influence the spatial position of the mandible. We must also remember that in the very young child it is an anatomical fact that the glenoid fossæ are shallow, and that the articular eminences are almost non-existent. It would not require a great muscular effort to bring the condyles into a position dictated by the tongue and its environment.

We may all have heard of postured occlusions; how, for instance, a mandible will posture forward to effect a lipseal. I was interested several years ago to find two different types of these; one where the mandible postured forward from its position of maximum cuspal occlusion, and the other where the mandible postured forward *into* a position of maximum cuspal occlusion. The idea formulated in my mind at that time that the difference was related to the muscular field into which those teeth developed. If there were a postured muscular environment to start with then the teeth would erupt into maximum occlusion in that postured position. The lip morphology seems to be of secondary importance in that this type of posture could take place *not necessarily* to effect a lipseal. The former type of posture, where the mandible postured forward out of the position of maximum cuspal occlusion, was usually a conscious effort to try to keep incompetent lips closed.

The idea of a postured muscular environment was kept very firmly in mind, and in all my cases that I subsequently examined I looked specifically for the following points:—

1. The relation of the rest position of the mandible to the occlusion. I shall elaborate on this in a moment.

2. The position of true centric relation. In examination an attempt was made to dissociate the mandible from any muscular control, in order to see where it placed itself in relation to the upper teeth.

3. The path of closure from rest to occlusion.

4. The starting position of all functions of the tongue and mandible, including swallowing and speech.

5. The pattern of mandibular movement during speech.

A picture began to emerge which appeared to me to substantiate many of my earlier thoughts on postured occlusions.

First of all the rest position must be discussed.

REST POSITION

The pioneer work of Thompson and Brodie (1942) and Thompson (1946, 1949) is familiar to most of us. A resting position of the mandible was defined with the upper and lower teeth separated, perhaps 2–3 mm., and the intervening space was called the "freeway space", subsequently the "interocclusal clearance". Brodie postulated that this was established at birth and remained more or less constant throughout life. Thompson and Brodie deduced that the spatial position of the mandible was an individual characteristic which remained relatively stable, and was part of the inherent growth pattern of the face.

They furthermore defined the path of closure of the mandible from rest to occlusion as a hinge movement with the lower incisors moving upwards and forwards. The condylar movement was almost entirely rotation with occasionally slight translatory movement.

Ricketts (1952) began to throw some doubts on the constancy of the rest position, and he showed that Angle Class II cases exhibited a greater interocclusal dimension than Class I cases; that there was a more distal path of closure with more translation than rotation of the condyle. He felt that this forward position or posture of the mandible was conditioned in the interest of respiration and/or speech.

Atwood (1956, 1957, 1958), in a cephalometric study of the rest position of the mandible, compared pre- and post-extraction records in a group of prosthetic patients. He found that there was a considerable variation in the rest position, some cases showing increase in the vertical dimension and some showing decrease. He also repeated the observations after the dentures were made. The resting vertical dimension was often different, depending on whether the dentures were in or out of the mouth.

Berry (1960) has thrown some doubts on the constancy of the rest position and has discussed several denture cases where the rest position has changed and produced symptoms accordingly.

In my clinical examinations I found many cases where the resting position of the mandible was the usual 2–3 mm. open from the occlusal position, but the important point was that neither the occlusal position nor the resting position coincided with the true centric relation of the mandible to the maxilla. We might say that as well as having a so-called "displaced occlusal position" we had a displaced, or postured, resting position. Before going any further it is necessary to clarify the terminology.

The displaced occlusal position is one which is displaced from centric, but the word "displaced" means to put out of place; as in my view this occlusion is not produced as a result of a mandibular displacement I much prefer to call the occlusion a "postured occlusion". I used also in the beginning to think in terms of a postured rest position. Whereas, however, an occlusion of any sort can be related to centric occlusion as a yardstick, no definition of rest position has ever related this position to the centric relationship of the mandible. The rest position of the mandible is that position where the mandible is suspended involuntarily away from the teeth. It may well be postured forward as shown by Ricketts (1952) in both Angle Class II, division 1 and division 2 cases—but it is still the rest position; and as Ricketts has shown, this rest position can alter during orthodontic treatment. In the past our thoughts have been subconsciously centred around a rest position which was somewhere along the path of centric relation and which was immutable, but this, it

is felt, is not a correct assumption to make. If the muscles attached to the mandible are held by an involuntary process off the line of centric relation, to produce a postured occlusion, then the resting position of those muscles can be expected to follow suit. If the basic underlying posture of the mandible alters, then I believe the rest position will probably alter too. The terms "posture" and "rest position" are not used synonymously because they are considered to be two entirely separate entities.

There are many clinical ways of determining the rest position of the mandible, but what must always be realized is that this rest position may well be right away from the line of true centric relation. Furthermore, it must be realized that whilst one can show, by trying to dissociate the mandible from its muscular control, the third position of centric relation, it is often impossible to obtain a resting position directly along the line of centric relation. The mandible involuntarily returns to its original resting position. Now this is an important observation. It means that if one is examining clinically a path of closure from rest to occlusion, without having first established where the rest position is in space, then one may well be obtaining some false information. It should be stated here that it is possible to observe a "displacement" within a path of closure which has itself been proved to start from a postured position. The term "normal path of closure" is therefore an empty term unless care is taken to define the beginning and the end.

In the clinical examination observations were made of the starting and finishing positions of the mandible during function. In the cases under consideration it was not surprising that the rest position was the functional centre for such movement; the rest position and not centric relation. Swallowing could take place with or without tongue-thrusting activity, with the teeth either in the postured occlusal position or in the rest position. The mandible did not return to a position of centric relation. Speech was examined by getting the patients to count from sixty to seventy (those that could count), and to say the letters of the alphabet. I also talked to them about school and many other things, and found here also that such speech was in the main based around the functional centre. That functional centre coincided with the rest position of the mandible, and not with any point on the path of centric relation.

All these observations on the rest position could surely be explained if we were to accept the tenet that both the occlusal and rest positions of the mandible are subservient to an underlying mandibular posture; that this mandibular posture is produced by the tongue, lips, and cheeks, and that it is within limits a variable entity. It would suit our appreciation of this concept very much better if we could refer to the rest position in our minds as the rest position of the muscles of mastication, instead of the rest position of the mandible. The rest position probably reflects the relaxed position of the muscles of mastication, just open from the occlusal position, but its position in space is governed by the posture of the mandible. If the basic posture of the mandible alters, then the rest position will follow.

PATTERNS OF MANDIBULAR MOVEMENT

An interesting feature of very many of the cases under observation was that the mandible was very consistent in moving towards the side of posture in speech. Furthermore, it became apparent that even if the occlusion had returned to centric, either by itself or by treatment, the asymmetrical pattern of movement still persisted. There were a number of cases, however, where the pattern of movement of the mandible was away from the side of posture.

If we accept the philosophy that the occlusion is produced primarily by the spatial position of the mandible and not vice versa, we find that a number of our present problems begin to resolve. At least we begin to find logical reasons for some of these problems. These may be listed:—

1. Occlusions can change without us altering them. In Miss Bonnar's paper to this Society in 1960 (Bonnar, 1960) she showed that the incidence of centre-line discrepancy was as high as 56 per cent in her Belfast cases,

and 40 per cent out of a total of 52 cases in the London cases of Miss Clinch. The age range was through the deciduous dentition until the complete eruption of the permanent incisors—and we must remember that cases where extractions had been carried out were eliminated. Miss Clinch, in discussion, said that of her cases only 5 had a centre-line shift at the age of 14 years. There was, she suggested, a tendency to self-correction during the development of the full permanent dentition. In May, 1960, Leighton showed to this Society a very important series of models. He was discussing developmental changes in the deciduous dentition, and he found that in a series of 212 cases deterioration of occlusion occurred as frequently as did improvement. He found 40 cases showing change between the ages of 3 and 4 years. He felt that these changes were not usually part of a developmental pattern, but rather chance manifestations of the effect of environment on the occlusion. He found evidence in most cases of a change in mandibular position as manifested by an alteration in the centre-line relationships of the two arches. One case was shown where the occlusion became very much more postnormal, and a complete buccal occlusion developed. There is no doubt whatsoever in my mind that the occlusion had originally developed to the maximum cuspal position with the mandible held forward in a postured position. At some later stage a reversion had taken place, and the mandible had assumed a more correct anatomical position in centric relation.

Hellman (1942) showed an interesting fact in discussing the incidence of normal occlusion. He found that the incidence of normal occlusion varied with age:—

At 5 years of age there was a normal occlusion in 68–70 per cent of cases. As age advanced there was a constant increase in malocclusion and a decrease in the normal. At 8–10 years of age there was a complete reversion of the above ratio, with normals down to about 30 per cent, and after that age normals started to climb again. Humphries and Leighton (1950), in their classical survey of anteroposterior abnormalities in pre-school age children, showed that there was a tendency for postnormal occlusions to increase slightly over the age-range examined. Of even greater interest is the fact that whilst at the age of $2\frac{1}{2}$ years postnormal occlusion amounted to 24·4 per cent, a group of parents also examined by them showed a postnormality of 33·8 per cent. Prenormal occlusions in children tended to decrease, and this decrease was also carried forward to the adult group.

I am confident in my mind that what is obscuring the picture of the normal development of an occlusion, whether that occlusion be a malocclusion or an ideal occlusion, is simply an unpredictable alteration in the relationship between the mandible and the maxilla.

Why should the occlusion change? Maybe we can say that the occlusion changes because of an uncomfortable biting position, possibly stimulated by the eruption of further teeth. In many cases, however, the changed occlusion is a worse one, with fewer teeth in contact. Sometimes even a marked open bite is produced by this change, with perhaps only one or two teeth in contact. The teeth out of contact may show wear facets, indicating that they were at one time in occlusion with opposing teeth. To me it is an untenable theory that the original occlusion had been produced or induced by an initial contact and displacement forward or laterally into a position of maximum cuspal occlusion. If the protective reflex mechanism had produced the initial postured occlusion by inducing a displacement, why did it not work a second time when the mandible decided to return to its position of centric relation?

2. Occlusions change, sometimes for the worse, during the course of orthodontic treatment, such a change not being ascribable directly to actual treatment. Overjets may increase; open bites may be produced; and sometimes complete buccal or lingual occlusions, often unilateral, appear to develop suddenly.

3. So-called mandibular displacements are very common indeed. Heath (1947, 1949) found in an investigation of 120 Australian aboriginal children that 42 per cent of them showed a difference between the normal biting

position and the most retruded position of the mandible. The latter was not forced retrusion. He found also that the position where the teeth occluded had often produced wear facets, showing that function was taking place in this position and not in the retruded position.

Among a series of 250 new orthodontic patients examined by myself recently, 49·6 per cent showed an occlusal position which was not centric occlusion; 42·8 per cent of the total postured *laterally* into occlusion, and of these lateral postures 79·4 per cent showed a mandibular resting position which was lateral to the line of centric relation. It is of interest also that 61 per cent of all postured occlusions showed a persistent thumb- or finger-sucking or nail-biting habit; whereas of the 126 cases showing no posture at all, only 40·4 per cent showed the persistent thumb- or finger-sucking or nail-biting habit.

T. Wingate Todd (1930) has shown instances where the condyle has been made to function out of the glenoid fossæ and beneath the articular eminence, with no apparent damage to either the condyle head or the eminence. Schweitzer (1951) in his *Oral Rehabilitation* shows three skull photographs from Todd's collection. In each case the teeth occlude, but with the condyle forward on the articular eminence. In describing these photographs, such statements as "mandibular body short" show a non-comprehension of the true features of the cases. Many of these cases are not resolved simply by removal of the "initial contact"; when the initial contact is removed one often finds a further tooth giving an apparent initial contact and a similar mandibular displacement.

Try to visualize what the occlusion was like before the tooth in initial contact erupted. Was the occlusion based then around centric relation? Cases occur where it was not, and a similar postured occlusion was present beforehand.

4. Some of these postured occlusions strongly resist attempts to build the occlusion around a true centric position, and function will persist in taking place around a postured position.

5. These postured occlusions rarely cause temporomandibular joint disorders in young children. I believe that the reason for this is that the postured occlusion itself is not conducive to temporomandibular joint derangement. If the postured occlusion reverts to centric relationship during the time when development of the occlusion can still take place in a vertical direction, then I think it is possible that the teeth will erupt to give a balanced occlusion in this position. There will, under these conditions, be no undue stress on the temporomandibular joint structures.

If, however, the mandible attempts to revert to centric relationship after the period when compensating tooth movements can normally be expected to take place, then the mandible will be trying to function in an imbalanced position, that is *centric* relationship, when the occlusion is built around a *postured* relationship. The true effects of a displacing activity are then seen. It is my submission, therefore, that it is not the so-called displacement which initiates spasm to the muscles related to the temporomandibular joint, but the attempt to return to centric. It is only at that time that the displacement really becomes a displacement, and muscles are thrown into spasm by the mandible trying to find a balanced occlusal position for function.

It is doubtful if proprioceptive impulses from the periodontal membranes of teeth in initial contact are sufficient to maintain a displacement; it is probably the proprioceptors in the muscular environment, plus the sensory contact between the tongue, lips, cheeks, and teeth, that maintain the posture. When the mandible tries to function in true centric relationship the proprioceptors in the periodontal membranes are not sufficient to maintain the "displacement" without causing severe spasm of the muscles attached to the mandible. The muscles go into spasm, probably in an attempt to hold the displaced occlusal position without the reflex neuromuscular mechanism that produced the posture in the first place. This takes place, therefore, only at the stage where the mandible is trying to function in the true centric position.

6. Another problem which may be partially explained is that of traumatic occlusion. My theory will explain why many occlusions

which are potentially traumatic fail to produce evidence of trauma. We call some occlusions "potentially traumatic" if they vary from our mechanical concept of how that occlusion should function; and we think that trauma may be caused to the teeth themselves, their supporting structures, and to the joints. Explanations as to why there is often no tangible evidence of trauma in these cases vary considerably. Conversely, there are times when we produce by orthodontic means a traumatic bite relationship, and we wonder why a mandibular displacement is not induced as a protective mechanism. In these cases we see, not a mandibular displacement as a reflex avoiding action, but loosening of the teeth in question.

7. Next we have the question of wear facets on the teeth. This is where one must be very careful in examination. It is not sufficient to note that facets are present and that this is evidence of displacement; one has carefully to note the distribution of such facets throughout the mouth, and where they are on each particular tooth. After this comes an assessment of how they could have been made. Many posture cases show a distribution of wear facets which exclude the tooth or teeth in initial contact; or if these latter teeth show facets, then an examination of the upper and lower arches in centric relation will quickly demonstrate that such facets could not have been produced by the mandible functioning in centric relation. I believe this further supports the contention that the postured occlusion is the true functional one at that time. One must visualize mastication and grinding as taking place around a functional centre which may not be the true centric relation of the mandible. If the wear facets indicated a desire on the part of the mandible to return to true centric relationship, then it must be obvious that the first teeth to be worn down would be the teeth in initial contact. You may recollect that it was shown that bruxism could take place with the mandible in a postured position in some Class III cases that I reported on some years ago (Blyth, 1959a).

Before discussing the mechanism of postured occlusions we may ask ourselves what happens to those postured occlusions when there is no attempt by the mandible to return to centric relation. The answer is most probably that nothing happens to them: they just go on functioning in the postured position without producing trauma to the teeth or clinical evidence of temporomandibular joint disorder. This is a logical explanation of why certain adults with a so-called mandibular displacement do not produce the joint troubles which might be expected. No one should attempt to do an occlusal rehabilitation on an adult patient after merely finding that the occlusion present was not centric occlusion. If a postured occlusion is found and an attempt is made by restorative dentistry, or grinding, to establish the true centric relation of the jaws, *and the muscular environment maintaining the postured relation is not altered—or does not alter*, then the newly balanced centric occlusion will itself cause symptoms of distress. It will, in effect, give an unbalanced occlusion when the mandible is trying to function in the postured position. This may very well be the explanation of why, in the case of histories of temporomandibular joint symptoms, trouble has started with an occlusal rehabilitation.

Schwartz (1959) in his *Disorders of the Temporomandibular Joint* (p. 423), in discussing a case where a patient had undergone many attempts at occlusal rehabilitation without success, quotes the patient as saying that she felt that her bite was originally an abnormal one and a so-called normal occlusion was wrong for her.

In another case (p. 420), "the patient states that the symptoms began three months before, following the grinding of his teeth for the relief of ringing in his ears . . . the patient felt that if by some means his occlusion could be restored to what it was before grinding his troubles would be over".

In discussing the reasons for posture and return to centric relation, one further thought should be introduced into the argument at this stage. It appears that in some of these posture cases there may well be a basic asymmetrical bony relationship between the maxilla and mandible in a lateral direction. This is a clinical impression, and I would stress

that this malrelationship has been noticed when the mandible has been held in its position of centric relation. Little can be added to the possible causes of a postured occlusion other than the points already brought up. The work of Fish (1961), in a recent study of edentulous patients, appears to support my views on the importance of the tongue in positioning the mandible. Atypical patterns of mandibular movement may indicate that a posture is present, but there is no definite proof. Sensory contact between the lips, tongue, teeth, and cheeks, plus possibly some outside environmental factor, such as a habit activity acting as a reinforcing agent, may induce the posture initially, by reflex activity. Into this position the teeth develop.

What may break such a posture?

We have seen that the reflex chain holding the mandible in a postured position may be broken without reference to any known factor. If a thumb- or finger-sucking habit is acting as a reinforcing agent in a conditioned reflex arc, then mere cessation of this could, by breaking the reflex chain, allow the mandible to return to centric relationship. Alternatively, I think that the development of a conscious awareness of the true position of the mandible is possible. It may also take place by altering the occlusion itself. For instance, a high bite on a permanent restoration may permanently break the postured occlusion and allow the mandible to try to function in true centric. Many cases are given in the literature of temporomandibular joint disorders being initiated by such conservation treatment. But, as Schwartz says (p. 435), once dysfunction appears, in many cases the process is no longer reversible, and cannot be relieved simply by the adjustment of the occlusion. Removal, then, of the high bite on the permanent restoration may therefore have little or no effect, as the mandible will continue to try to function in its newly found centric relationship.

Orthodontic treatment itself may also serve to break the reflex chain maintaining the postured occlusion; and it can do this of course by altering the environment of the tongue. Retraction of the incisors will give the tongue a different field in which to function and may well induce (reflexly) the mandible to return to centric relation. Supporting evidence for this is the odd case which apparently gets worse during treatment. We have all experienced the type of case where, on retraction of the upper incisors, little or nothing happens to the overjet. We can occasionally put this down to bad mechanics; but what happens in some cases is that as the upper incisors are being moved lingually, the whole of the mandible is moving lingually also.

The reverse is also true, of course. Some cases with postures will not respond to treatment calculated to correct that posture. We do not use Class II intermaxillary traction much these days, but many of us can surely recollect cases where the Class II intermaxillary traction produced little or no reduction of overjet in a Class II, division 1 occlusion; and we go on using stronger elastics to no effect. If the mandible will function forward in a postured occlusion the effect of the Class II elastics will be nullified. Similarly, with Andresen-type appliances, a mandibular posture can in some cases be *induced*, and it will be impossible to retract the upper incisors by this means. Unfortunately, it is very true to say that the induced postured occlusion may lead the unwary operator to assume that he has produced a perfect result in a very short space of time. It is only after the fee has been paid that the mandible returns to centric relation!

Extraction of teeth in initial contact still often allows a postured occlusion to persist, and may then demonstrate other initial contacts. There are cases which show postured occlusions right from the start, before the teeth in initial contact have erupted. It cannot be believed that teeth will erupt and prop open the bite. It is obvious that the teeth in question have erupted with the jaws held by the surrounding musculature in the postured position. The so-called "initial contact" was not present and never has been present. It has only been found by us because we have been used to relating function of the jaws to a mechanical position. The latter is a concept produced mainly by a study of the bones and

joints *in vitro*, together with the occlusal surfaces of the teeth.

It may be an advantage to restate my hypothesis that the developing occlusion does not dictate the spatial position of the mandible, but the position of the mandible dictates the occlusion. We can visualize the occlusion as developing in two phases: (1) The first where the teeth erupt into a position entirely dictated by the surrounding musculature. Final occlusion of the teeth is probably achieved by cuspal guidance, but the latter serves only to guide the teeth into their positions of maximum contact, and does not serve to alter the basic position of the mandible. This first phase always occurs. (2) The second phase may or may not take place in any one individual person. If the position of the mandible in the first phase was postured, the mandible may later return all or part of the way to centric relation; if it does this when accommodating tooth movements are possible, then it is probable that a balanced occlusion will result. If, however, the mandible returns to centric relation and accommodating tooth movements do not take place, then we have a condition which is the reverse of the first phase. The occlusion is now trying to dictate the position of the mandible, and it is this particular situation which cannot be tolerated physiologically.

There is an alternative second phase which may take place if the posture of the mandible coincides with centric relation in the first phase. It would be an over-simplification of the case to state dogmatically that initial contacts never set up a displacement. They may well do this in an established occlusion, but not to the extent that we orthodontists at present imagine. We would, therefore, in these conditions see an occlusion, which has developed in centric relation, go to a displaced position; a displaced position as opposed to a postured position. The whole mechanism of reflex-avoiding activity as described by Ballard (1951) and Grewcock and Ballard (1956a, b) may well now take place.

We have to appreciate that there is a functional centre for the mandible to work around. This functional centre is not directly dependent upon the shape of the joints or the shape of the teeth, or upon a theoretical centric relationship of the jaws. Furthermore, it may alter at times. This functional centre is created entirely by musculature and is an important factor to be considered in the analysis of occlusions. It may logically be of prime importance also in the field of prosthetics.

TREATMENT

No attempt should be made to correct all these postures. If the case requires orthodontic treatment from other considerations, then measures should be brought into the treatment plan to try to correct the posture. Each case is analysed, and models are set up on two anatomical articulators—the first shows the position of centric relation, and the second the postured occlusion. It should be pointed out that in many cases function will persist in taking place in a postured position, and it often becomes extremely difficult to reconstruct the occlusion around the position of centric relation. If, on the other hand, the occlusion does not show other abnormalities, then I prefer not to embark on active treatment, but merely to keep the case under observation.

CONCLUSION

Any future assessment of occlusal changes must surely need to contain positive information on the true position of the mandible in relation to the maxilla. It will not be sufficient for us to accept automatically that the mandible is static in relation to the maxilla, and that any changes we observe are necessarily due to movements of teeth.

ILLUSTRATIVE CASES*

Case 1.—This showed a girl who had gone from a postured relationship in the 1957 models to centric relationship in 1960. The upper and lower centre lines were correct initially, but in true centric relationship the lower centre was 2–3 mm. to the left of the upper. It was noted clinically that the centres had changed in 1958. The child was filmed in 1960; she showed a resting position which was postured to the right of the path of centric relation, and all function started from this position. She now shows a rest position which is open from the position of true centric occlusion, and all function takes place from here. In this case both rest and occlusal positions have altered, but not simultaneously.

* These were accompanied by a film.

Case 2.—This is a young patient with a very severe Angle Class II, division 1 incisor relationship. She had incompetent lips, but little or no abnormality in tongue behaviour. Articulated models were seen, showing the position of true centric relation and the postured occlusion. The latter was approximately a full unit forward of centric. Clinically, it was observed that the rest position was open from the postured occlusal position, and that all function of the mandible started and ended with this position. The position of centric relationship was demonstrated a number of times, but the mandible involuntarily returned to its original postured rest position. The condyles could be seen coming forward and functioning in the forward position.

Case 3.—A case which was diagnosed in 1959 as an Angle Class III occlusion with 1| inside the bite, and an initial contact on this tooth. Treatment was planned, but when the patient next attended there was an edge-to-edge bite relationship and no apparatus was indicated. When the child was seen again in December, 1961, there was a marked Class II, division 1 incisor relation with a new "initial contact" on |6. She had still had no treatment; the mandible was returning to its position of centric relation.

Case 4.—This case showed a Class I occlusion with 1| inside the bite. Rest position was open from this occlusal position, and an initial contact was shown on 1| with a forward "displacement" into occlusion. There was a wear facet on the labial surface of 1| and on the lingual surface of 2|. This latter tooth showed marked mobility, with a forward movement in the alveolar bone and considerable gingival recession. True centric relation, however, showed 1| to be a considerable distance in front of 2|. The rest position was postured forward, and was open from the postured occlusal position. All functions were shown to start and end at this position.

Case 5.—This was a boy of 8 years who showed a considerable tongue irregularity but who had already returned from a postured occlusal position to true centric relationship. This jaw relationship showed a contact on C| and C| only, and all other teeth in the mouth were out of contact. It was impossible to get this child to occlude in any other position. There were, however, marked wear facets on all 6-year-old molars, and some deciduous molars, showing that these teeth had been in occlusion at one stage. The wear facets were demonstrated both clinically and on the models.

Case 6.—This young patient attended in October, 1961, with the complaint that she could not get her teeth together on one side when she was eating, and that her jaw slid over to one side. A bite analysis showed marked "displacement", and it was felt that this child had returned to centric relation in function.

She was first seen in 1958, however, and models taken at that time showed that the postured occlusion was present then. No displacement or posture was clinically noted at that time, and this fact is a common finding amongst posture patients. She had a rest position which was lateral to the line of centric relation and all function started from this postured position. Speech was also to the postured side.

Case 7.—This case demonstrates the development of temporomandibular joint symptoms. A series of models were shown dating from 1956 to 1960. The patient had a fairly normal incisor relationship, and in each set of models the centres were correct. A damaged earlier set taken in 1955 showed the same thing. Orthodontic treatment involved extraction of 4|4 and the alinement of |1. From August, 1958, she started getting severe temporomandibular joint symptoms, with clicking and soreness in the masseter and temporalis muscles. I could detect no displacement whatsoever at this stage. She had a history of rheumatic joints and of severe rheumatism in the family, and for the parents' sake she was referred to a rheumatologist for a report, which was negative. She was only 12 years of age at the time the symptoms developed, and an oral surgeon suspected possible impaction of second permanent molars. I inserted a bite plane early in 1959 as an empirical measure, and this immediately began to control the symptoms. After several weeks without symptoms, with control of pain and relaxation of the musculature, I began to find evidence of a displacement. With the bite plane in she began to occlude in true centric relation, and here the lower centre was markedly to the left of the upper centre. Without the bite plane she went to the "displaced" position where the centres were correct. Bite analysis, using adjustable articulators, showed that the "initial contact" was on |3. In the early models, however, the postured occlusion was there, even though |3 had not erupted.

Treatment consisted of orthodontic treatment to move |3 buccally, and several visits at which occlusal grinding was carried out. The appliance was gradually left out, and for 15 months the patient has not been wearing an appliance of any sort, and has no symptoms.

Case 8.—This patient was filmed three times. She had |2 inside the bite, with a resting posture to the left of centric relation. All function was shown to take place from this position. The position of |2 was corrected, and there was then shown to be a new "initial contact" on |6 with still a posture to the left. She was refilmed for the third time 15 months after the treatment had been carried out; there was still a postured rest position to the left of centric and still a mandibular movement to the left in speech.

Case 9.—Here was shown an adult patient, aged 39 years, who had a postured occlusion to the left of centric relation. The resting position was just open from the postured occlusal position, and the mandible moved to the left from this position in speech. Centric relation showed a contact on 8| only. The patient had never had any temporomandibular joint symptoms.

Case 10.—This case showed well the return to centric relation during the currency of orthodontic treatment. A series of models were shown initially which had been taken over a period of 10 years, and a postured occlusion was shown to be present right from the beginning. During treatment to correct a Class II, division 1 incisor relationship the mandible returned to centric relation, and there was shown to be an asymmetry in the lateral direction between maxilla and mandible. A complete lingual occlusion of the left lower buccal segment was demonstrated and the patient was now seen to function entirely in this newly found centric relationship. She moved still to the side of posture in speech.

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DISCUSSION

Dr. J. R. E. Mills congratulated Mr. Blyth on the great amount of effort and thought he had put into the paper. Nevertheless, Mr. Blyth would not be surprised if he did not agree with some of the findings.

It was interesting to look, not at Man, but at other animals, in which the posterior teeth had higher cusps. Such animals could not survive if they had a malocclusion, and therefore normal occlusion was virtually universal. It had been shown by Warwick James in the bat and the shrew, and by Gaunt in the cat, that the teeth develop within the alveolus in such positions that they move directly into occlusion as they erupt. There was no question of muscular involvement or of abnormal skeletal patterns. Nevertheless, the teeth must be under the influence of the surrounding muscles, and one could only assume that the muscular forces in ideal occlusion exactly balance.

In Man the picture was different owing to genetic variations. One had abnormalities of the skeletal pattern. The surrounding musculature up to a point would compensate for this, but beyond a certain stage did not seem able to do so and indeed often made a malocclusion worse. An example of this was seen where the skeletal pattern produced an increased overjet. In these cases there was a tendency to compensate by the muscles holding the mandible in a false habit rest position, and bringing the incisors closer together. Usually the individual reverted to the true centric relation when the teeth were in contact in function. Very occasionally one saw an individual who actually chewed with the mandible displaced forward; he thought he had seen 2 or 3 such cases in the last 10 years. The individual usually reverted to the true centric relationship as the overjet was reduced. These cases were very rare and would fit in with Mr. Blyth's theory.

In the majority of cases where individuals chewed with the mandible displaced from the true centric relation, he felt that it was due to cuspal interference preventing comfortable occlusion in the correct position. The individual learned to avoid the uncomfortable tooth as a true conditioned reflex. He had three points to support this view; first, the individual very quickly reverted to the true centric relation if the need for the displaced position was eliminated. Indeed, the fitting of an appliance with bite blocks over the posterior teeth would eliminate the displacement in a matter of minutes. Secondly, there was usually another reason why the tooth in initial contact was misplaced. Very often it was due to crowding or abnormalities in the skeletal pattern. Thirdly, while the tooth was in its displaced position, it was very difficult to persuade the individual to close in the true centric relation; experience had told him that this hurt and he fought to avoid the tooth reflexly.

Mr. Blyth had suggested that in the displaced position fewer of the teeth were in contact than in centric relation. Dr. Mills suggested that this was not the point; in the centric position one of the teeth hurt! Mr. Blyth had also suggested that there might be more than one "initial contact". This was true, and for this reason mandibular displacements should usually be treated early, otherwise teeth erupting later would often develop a good occlusion in this displaced position, and it could be very difficult to correct the mandibular displacement because of this fact. This may account for pain occurring after the apparent correction of the mandibular displacement.

He found it difficult to comment on the film. He had watched it carefully and could find nothing in it that made him change his views.

Mr. L. H. Russell asked if Mr. Blyth had related posture to the patient's "handedness", and Mr. Blyth replied that he had not.

The President said that there was no doubt that the ability to see the motion reproduced again was most valuable and there was a tremendous amount to be learnt by a study of cinematography of the action of the teeth, which had never been seen before. Some orthodontists watched a patient and remembered what he did, and others would be much better if they could see it and sit down and look at it over and over again. It was a most valuable study and he congratulated Mr. Blyth on his excellent photography.

Mr. R. E. Rix said that in the film the third case had shown that at rest and in speech there was a slight overjet, but the mandible could be forced back a good unit. He asked Mr. Blyth how the child ate. Was the occlusion back to the forced position or was it in the forward position?

Mr. D. J. Timms said that with the electromyograph displacements could be detected down to a fraction of a millimetre. One saw them by the early or late onset of muscular contraction or by some inhibition of the muscles of mastication. The position of the teeth probably developed as a result of the musculature and growth of the hard tissues, and given the teeth in these positions the mandible had to occlude in the most favourable position. The patient often had to deviate a little to achieve this position, control being by reflex arcs within the trigeminal nerve from proprioceptors in the periodontal membrane, tendons, and (as established only last year in Sweden) the joint capsule. This showed particularly in Class III cases where there was a deep overbite and the mandible was forced forward, or Class II, division 2 cases where the mandible was retruded with a deep overbite. Certainly it was shown in cases of temporomandibular joint dysfunction, although there

were difficulties if factors were present other than displacement. These cases could often be cured if the bite was adjusted until the electromyograph recording showed no displacement.

He had the impression that Mr. Blyth had suggested that the occlusion was subservient to the position of the mandible. Of course it was the other way round, and the mandible's position was subservient to the occlusion and had to fit into the occlusion.

Mr. Blyth, replying, thanked Dr. Mills for opening the discussion. He did not think he could really answer the points raised because so much depended on a point of view. Each of them had a theory and, like all good theories, there was precious little to support them. He thought that the answer could be found if they went back far enough. He certainly thought that if they could go back to the beginning, as far as case records with children were concerned, the pattern of development could be found. The trouble was that they did not know at the start when they had an interesting case. They had to get into the habit of getting all their information on every case.

He had filmed several hundred children and had used about 5000 feet of colour film. He hoped that in due course some of that would be useful. He had wondered very much whether he should give the paper, but had decided that he had gone as far as he could on the clinical side. Much more information was needed, but that information had to come from more scientific sources —electromyography and radiography—and a technique had to be developed for assessing asymmetries in a lateral direction.

Mr. Rix had asked about posture during eating; he had not examined that. It had been in his mind to have a packet of biscuits handy but he had not got round to it! It would be a most useful thing to investigate.

A CASE OF MARKED ASYMMETRY OF THE FACE DUE TO A UNILATERAL CONDYLAR HYPOPLASIA

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INTRODUCTION

A FAILURE of growth of the mandible affects not only the skeletal but also the soft-tissue relations of the face. These relations are factors in determining the occlusion of the teeth, and it is important to realize the way in which they combine to produce an abnormal occlusion. In this case of unilateral condylar hypoplasia the occlusion which developed was a type of Class II, division 1. The large incisor overjet was partly the result of the post-normal position of the mandible and partly the result of the abnormal soft-tissue posture and behaviour. The lip posture was incompetent, and this allowed relief of antero-posterior crowding by incisor proclination and so increased the upper arch length. During function the incompetent lips were not sealed. An anterior oral seal was formed with the lower lip acting behind the upper incisors, and this, combined with the short incompetent upper lip, produced upper incisor proclination.

The significance of the above is in treatment planning, which has two aspects: (1) Correction of the changes produced by the post-normal lower lip in association with the anteroposterior crowding. This necessitated the retraction of the upper incisors from their proclined position. (2) The left horizontal ramus of the mandible, lower lip, and mandibular dental arch had to be brought forward by means of a bone-graft to complete the occlusal and facial correction. In its corrected position, the lower lip helped to retain the optimal incisal relationship produced by orthodontic and surgical means.

CASE REPORT

On March 12, 1954, the patient, aged 7 years 9 months, was examined and the following diagnosis made:—

"She has marked asymmetry of the face with a flattening of the dental arches on the right side due to failure of the growth of the left mandible. Radiographically, there is no true condyle but a flattening of the head of the neck of the condyle. The mandible swings to the left on opening but the ascending ramus is not fixed and is freely mobile anteroposteriorly. There has been early loss of deciduous teeth with some antero-posterior crowding in upper and lower jaws. A type of Class II, division 1 occlusion with the lower lip under the upper incisors."

The parent gave a history of a normal birth. There was no history of infection of the face, but apparently the patient had a discharging ear from the age of 6 months. The tonsils and adenoids were removed in 1953, but the discharge had continued.

Records were taken which consisted of models and radiographs. The radiographs taken were lateral and postero-anterior of skull, temporomandibular joint tomographs, and half-plate films covering $\frac{8—3|3—8}{8—3|3—8}$.

Arising from the examination it was decided to keep the patient under observation and arrange a combined consultation with an oral surgeon when the patient's skeletal growth was more advanced.

In September, 1957, when the patient was 11 years 3 months, at a joint consultation with the orthodontist and oral surgeon it was decided to extract $\underline{4|4}$ and retract $\underline{321|123}$.

Orthodontic treatment was started in January, 1958, when, following the loss of $\underline{4|4}$, a removable upper appliance was fitted to retract $\underline{3|3}$.

In June, 1958, following a discussion between the orthodontist and oral surgeon it was decided that the $\underline{32|}$ would form an obstruction to swinging the mandible to the right, and that these teeth should be moved labially.

In February, 1959, the tooth movements were complete. Records were taken which consisted of models, photographs, and a lateral skull radiograph with the teeth in occlusion. The upper incisors were in an unstable relation to the lower lip, and so required retention until the surgical operation, which was arranged for March, 1960, when the patient would be 13 years 9 months.

The amount of lengthening of the bone required was carefully planned pre-operatively, an articulator being constructed from the patient's own measurements.

At operation the mandible was sectioned in the region of the left angle, and the bone overlying the inferior dental nerves and vessels was removed from the point of the bone section to the mandibular foramen. The two ends of the bone could now be separated without stretching the neurovascular bundle, which was intact. The bone for the graft was removed from the left iliac crest. A large piece was trimmed to the required shape, while smaller pieces of bone were made into cancellous bone chips which were placed into the space between the separated fragments. The large piece was wired into place with the compact bone facing outward. The vertical height of the left side of the mandible was increased by splinting the teeth with an open bite between the left upper and lower buccal segments. The silver cap splints were worn for two months until May, 1960. In order to avoid vertical contraction on the left side following

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removal of the splints, an upper appliance was fitted with posterior capping on the left side. The capping was removed from one tooth to allow one pair of opposing teeth to come into occlusion before removing any of the capping from the other teeth. At the end of twelve months all the left buccal teeth were in occlusion. The

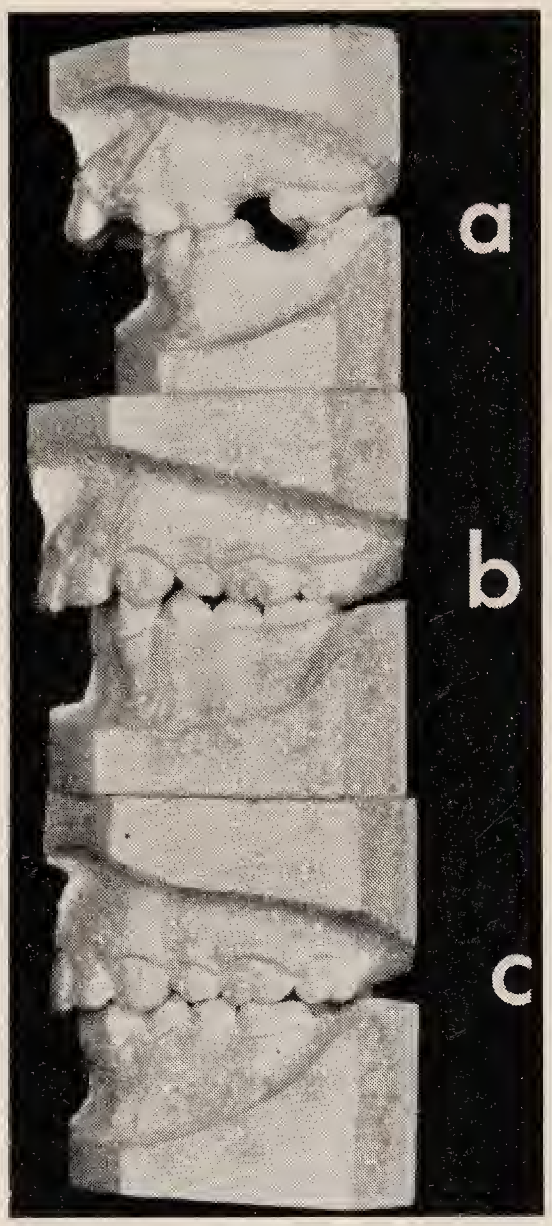


Fig. 1.—Models, left view. a, Before treatment; b, After orthodontic treatment; c, After surgical treatment.

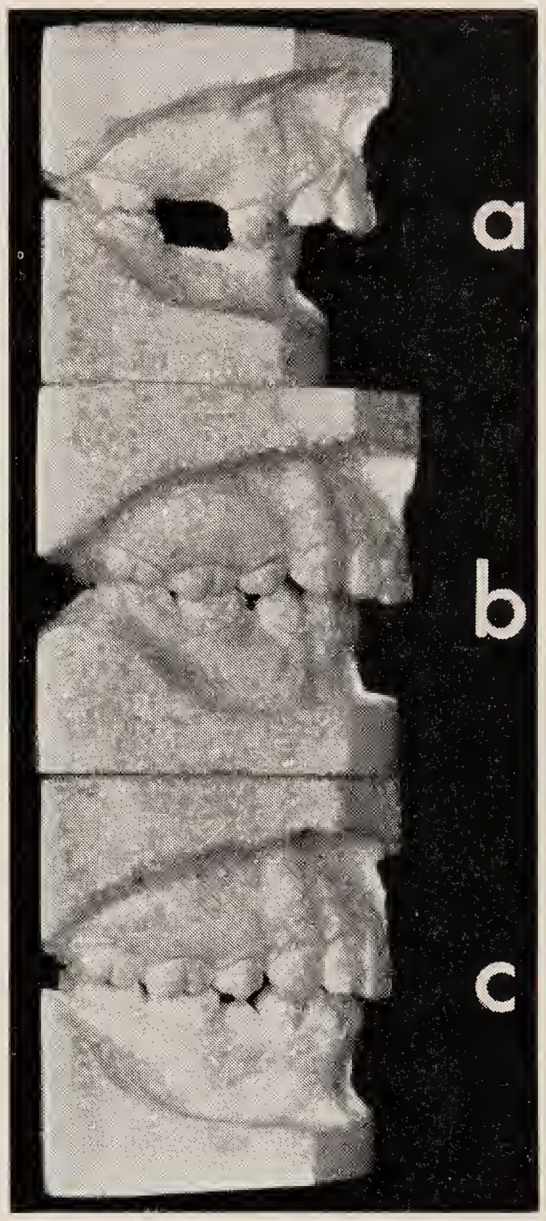


Fig. 2.—Models, right view. a, Before treatment; b, After orthodontic treatment; c, After surgical treatment.

Fig. 3.—Models, occlusal view. a, Before treatment; b, After orthodontic treatment; c, After surgical treatment.

removable appliance did not have a labial bow to control labial relapse of the upper incisors. This appliance was discarded in May, 1961, when the patient was 14 years 11 months.

Records were taken in November, 1961, which consisted of models, photographs, and lateral and postero-anterior skull radiographs with the teeth in occlusion.

CASE ANALYSIS

A study of the left view of the models (*Fig.* 1) shows that the overjet was partly reduced by orthodontic and partly by surgical treatment. At the end of orthodontic treatment there was little change in the left first permanent molar relationship. Surgical treatment brought forward the left horizontal ramus of the mandible,

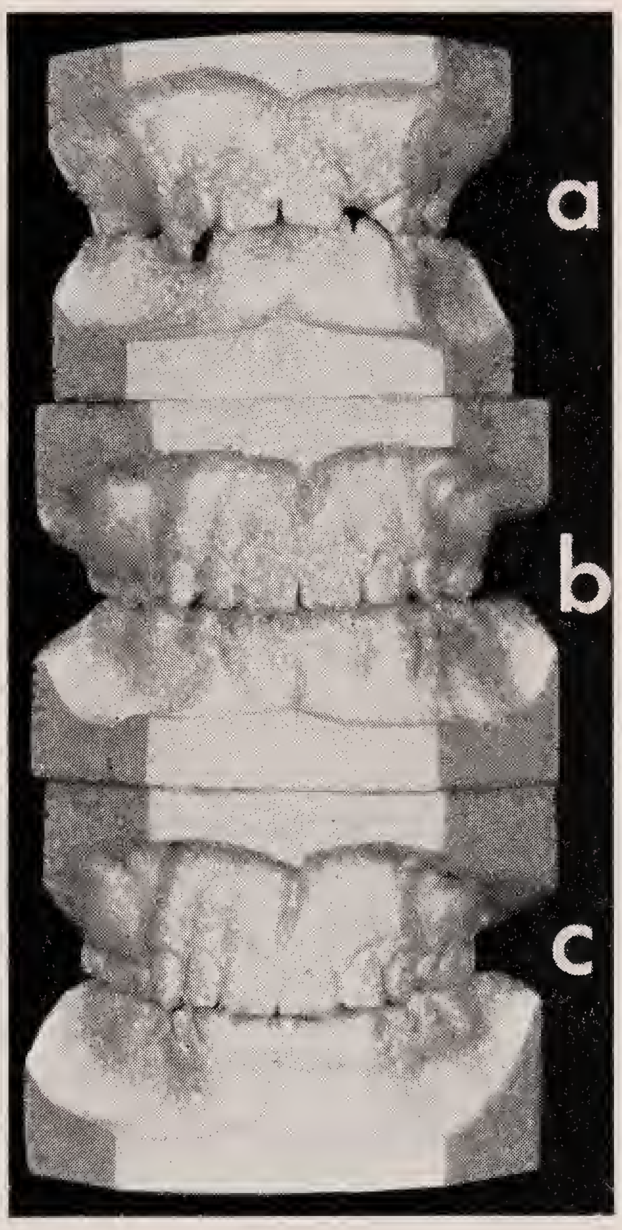


Fig. 4.—Models, front view. a, Before treatment; b, After orthodontic treatment; c, After surgical treatment.

and as a result of this the post-normal occlusion of the left first permanent molars decreased. The right view of the models (*Fig.* 2) shows before treatment a lesser degree of post-normality of the first permanent molar relationship compared with the left side. During the period of orthodontic treatment the right first permanent molar moved forward, decreasing the space for the right second premolar. It can be seen that the space opened again later. The occlusal view (*Fig.* 3) shows this well, and it also shows the

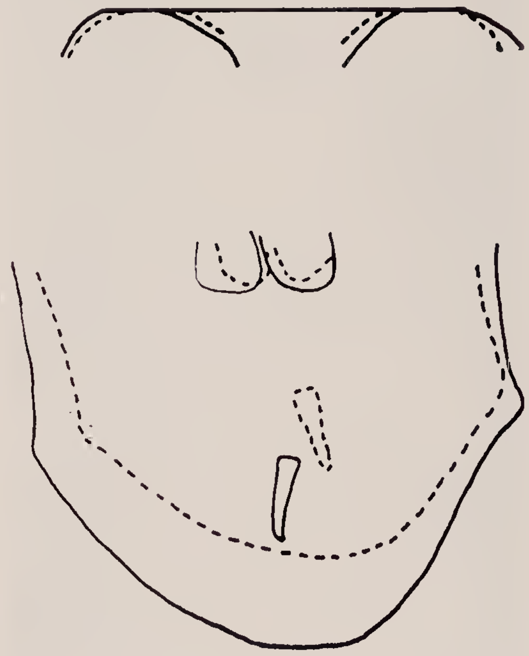


Fig. 5.—Superimposed postero-anterior radiograph tracing before treatment and after surgical treatment, showing the swing of the mandible to the right.

flattening of the dental arches on the right side with the right first permanent molar farther forward than the left. The front view of the models (*Fig.* 4) shows that before treatment the lower centre was over to the left, and this was unchanged at the end of orthodontic treatment. As the result of the bone-graft, the lower centre was corrected with the swinging of the mandible to the right. The swinging of the mandible to the right is best seen on the superimposed tracings of the postero-anterior radiographs taken before treatment and after surgical treatment (*Fig.* 5).

The photographs suggest that although the upper incisors had been retracted during orthodontic treatment their relation to the lower lip was not stable (*Fig.* 6 A). This was a clinical judgement, but the degree of circum-oral contraction seen on the profile view would support this, and a lip seal was only attained with conscious effort. This is in sharp contrast to the situation after surgical treatment (*Fig.* 6 B). The lips were still

incompetent, but a lip seal was easily attained without conscious effort. The upper incisors were in a stable relation to the lower lip, as evidenced by the fact that they had not relapsed labially although free to do so for eighteen months.

The differences between the right and left temporomandibular joints and vertical rami were studied from superimposed tracings of tomographs taken before treatment with the mandible at rest (*Fig.* 7). Tracings were superimposed on the external auditory meatuses, base of skull, and orbit. It can be seen that there was no true head to the condyle and no glenoid fossa on the left side. The articulation with the base of the skull was farther forward on the left side and the height of the vertical ramus was much less than on the right side.

A

B

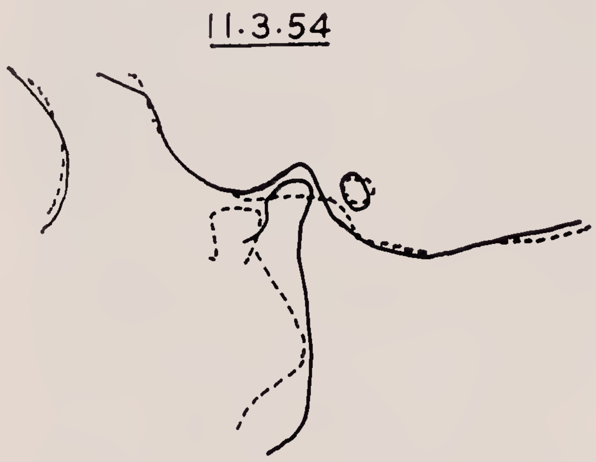
Fig. 6.—Full-face photograph with lips at rest and profile photograph with lips sealed. A, After orthodontic treatment; B, After surgical treatment.

Tracings of the lateral skull radiographs taken before and after orthodontic treatment were compared (*Figs.* 8, 9; *Table I*).

The dental base relationship as estimated by the difference between SNA and SNB was virtually unchanged during orthodontic

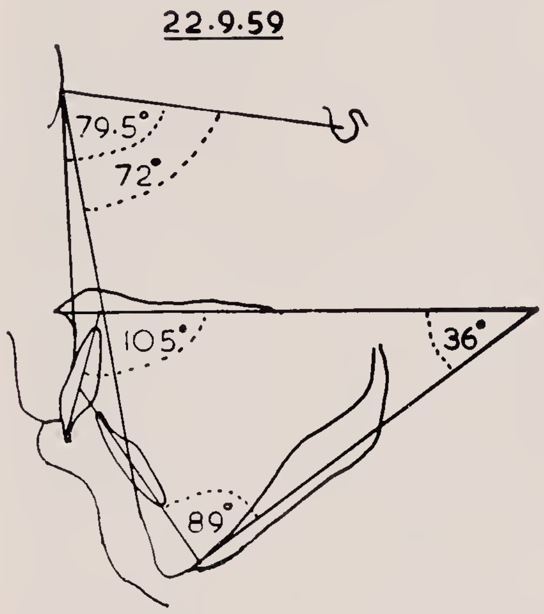
treatment. Using the maxillo-mandibular plane angle as a guide to the vertical relationship of the dental bases, there was a very slight opening during orthodontic treament.

The principal change resulting from the orthodontic treatment was the retraction of



BEFORE TREATMENT

Fig. 7.—Superimposed tomograph tracings before treatment, solid line right side, broken line left side, showing the differences between the temporomandibular joints and vertical rami of the two sides.



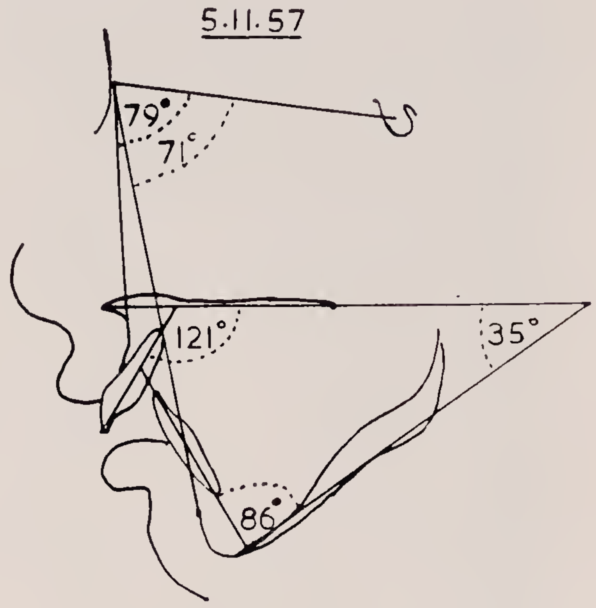
AFTER ORTHODONTIC TREATMENT

Fig. 9.—Tracing of radiograph, taken after orthodontic treatment with the teeth in occlusion, showing a change compared with the condition before treatment in the incisal but not the skeletal relationships.

the proclined upper incisors. The lower labial segment proclined slightly during orthodontic treatment.

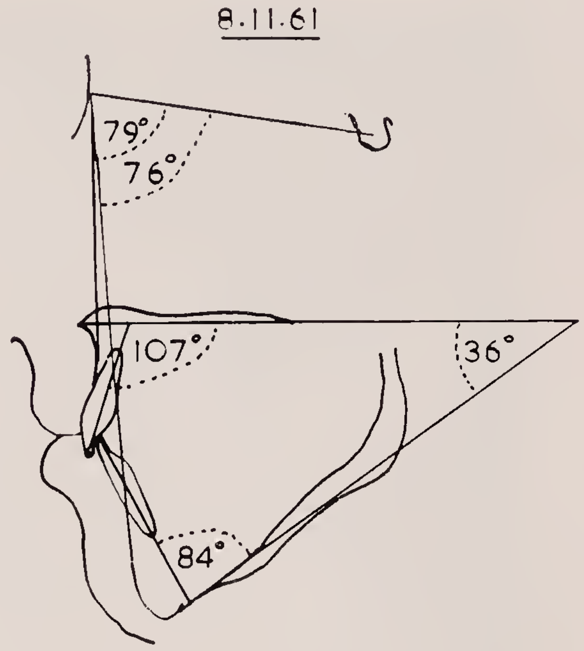
Tracings of lateral skull radiographs taken after orthodontic treatment and then after surgical treatment were compared (*Figs*. 9, 10; *Table I*).

The mandibular dental base was changed from a post-normal to a normal relationship by means of the bone-graft. The SNA–SNB difference was changed from 7° to 3°. The maxillo-mandibular plane angle was unchanged during the period.



BEFORE TREATMENT

Fig. 8.—Tracing of radiograph, taken before treatment with the teeth in occlusion, showing the skeletal and incisal relationships.



AFTER SURGICAL TREATMENT

Fig. 10.—Tracing of radiograph, taken after surgical treatment, showing a change compared with the condition after orthodonteic treatment in the skeletal relationships.

The angular relationship of the upper incisors to the maxillary plane remained virtually unchanged. The lower incisors retroclined slightly during this period and their angular relation to the mandibular plane was less than before orthodontic treatment.

To summarize, two courses of treatment were necessary—one orthodontic and the other surgical. The orthodontic treatment had as its

primary objective the retraction of the proclined upper labial segment. At the same time the upper arch was bowed in the right upper canine and lateral incisor region to facilitate the forward movement of the left horizontal ramus and swing of the mandible to the right on insertion of the bone-graft. The surgical treatment was neccssary to complete the occlusal correction and bring forward the lower lip to a position where it would help retain the retracted upper incisors The surgical treatment was mainly responsible for thc considerable facial improvement.

Table I.—Readings from the Tracings of the Radiographs shown in *Figs.* 8, 9, and 10

	Before Treatment (Nov. 5, 1957)	After Orthodontic Treatment (Sept. 22, 1959)	After Surgical Treatment (Nov. 8, 1961)
SNA	79°	79·5°	79°
SNB	71°	72°	76°
Mx–Md	35°	36°	36°
1–Mx	121°	105°	107°
$\overline{1}$–Md	86°	89°	84°
$\frac{1}{\overline{1}}$	118°	130°	133°

Enough has been said to indicate the importance of combined consultation between orthodontist and oral surgeon. The role of each will vary to some extent with individual consultants, but in most cases it would seem reasonablc that the orthodontist is in the better position to appreciatc the effects on the occlusion of the failure of bone growth. This is judged from a knowledge of how the occlusion would have developed had there been no interference with growth. It is not sufficient to assume it would have been normal. From this it is possiblc to decide the optimal stable occlusion and how much of the improvement should be achieved by tooth movement and how much by movement of the dental arch on insertion of the bone-graft.

Acknowledgements.—I should like to thank Professor C. F. Ballard for permission to publish this case. The orthodontic treatment was carried out at the Eastman Dental Hospital.

My thanks are also due to Mr. J. H. Hovell for his permission to report on the surgical treatment and to be present when he operated on the patient at St. Thomas's Hospital, London. I am grateful to the Radiographic and Photographic Departments of the Eastman Dental Hospital.

DISCUSSION

Mr. G. C. Dickson thanked Mr. Parker for a most interesting paper. He said that there were two points in it which he had found particularly interesting. One was that the affected condyle was farther forward in relation to the skull than the unaffected one, which appeared to be some attempt on the part of Nature to correct or compensate in some degree for the lack of growth.

The other point was that Mr. Parker said that thirteen years of age was a suitable time for the surgical operation. He himself would have thought that the mandible had yet further growth to makc. He wondered whether the unilateral growth which was a feature of these cases might carry the dental apparatus to one side. He wondered whether Mr. Parker thought any change in the centre line would be enough to matter.

Mr. J. H. Hovell said that he could comment on the forward positioning of the mandible. He had found, in condylar hypoplasias in which there was purely local abnormality in growth, that there was a tendency for the musculature, which was potentially normal, to try to overcome the deformity. Without any further growth of the mandible, both condyles would, during growth, be slung forward. The forward positioning of the mandible, in cases in which there were under-development and ankylosis, was the effort of the musculature after condylectomy to bring the mandible forward to its normal position relative to the skull.

Mr. Parker thanked Mr. Dickson for his remarks and said that Mr. Hovell had more or less covered them. He had been struck by the marked beneficial psychological effect that treatment had produced. The girl had quite changed, although she was never mentally abnormal. One had to do as much as one could as early as possible without prejudicing the end result. He had been very pleased with the mental response which had comc about as a result of the treatment. The patient is now "Twist" champion of Peterborough!

TREATMENT OF AN UNERUPTED FIRST PERMANENT MOLAR

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A REVIEW of the literature on unerupted or partially erupted teeth shows that very little has been published on first permanent molars. Most of it has been concerned with maxillary canines, and adequately reported by such authors as Kettle (1957), Hartley (1955), and Watkin (1947), who included treatments of unerupted upper central and lateral incisors.

As recently as 1960, however, Brenchley reported a case of submerged first permanent molars in a girl aged 11 years, and noted that an interesting feature was the hooking of the root apices at the lower border of the mandible. He suggested that although the tooth became 'inert' in development near the lower border, the roots continued to develop and became distorted on reaching the denser cortical layer of bone at the lower border. In 1959 Dixon, writing on impaction of first permanent molars, stated that the cause of a persistent impaction appears to be an early arrest of the eruptive process of the tooth by impaction against the second deciduous molar. Walpole Day (1946) reported cases of unerupted teeth which were surgically exposed and brought into occlusion. In his paper he described 4 cases which were designed to show that when all obstruction was removed from an unerupted tooth, that tooth would erupt into a normal position, or into such a position that simple orthodontic procedure would complete eruption. Again, however, the teeth concerned were upper centrals and canines.

In 1951 Glass published a paper in which he described a case of an unerupted first permanent molar, with second premolar and second and third molars in position.

This concerned $\overline{6|}$ in a female patient aged 26 years. The crown of this particular tooth was shown to be virtually destroyed, though doubt existed as to whether this was due to caries or osteoclastic activity.

In the discussion that followed this paper, Ballard stated that, having seen a number of cases of unerupted upper and lower first permanent molars, he had always assumed that the cause was the same as for deciduous unerupted teeth, namely, that the processes around the root resulted in ankylosis, which in the deciduous teeth reversed itself later on. Tulley (1950) also described 3 cases of unerupted deciduous molars, but made no observations other than that he felt it would be a long time before we fully understood the mechanism of tooth eruption.

Finally Gränse, in 1951, reviewing the literature of some 40 cases of what he refers to as infra-occlusion of the first permanent molars, suggests the possibility that a fibrous ankylosis from the alveolar bone to the area of resorption in the bifurcation might be the factor in arresting the normal eruption of these submerged or ankylosed molars.

He found that of 3 first permanent molars in infra-occlusion, extracted and examined histologically in serial section, none showed evidence of bony ankylosis.

CASE REPORT

The case reported here concerns a 13-year-old girl who in January, 1959, was referred to the oral surgery department for an opinion regarding an unerupted lower first permanent molar.

This was observed by her dental practitioner during routine examination, which assumed its early loss in otherwise intact arches. On taking bite-wing radiographs, however, it was seen that the cusps of a lower molar were just visible in the $\overline{6|}$ area.

On examination, the teeth present in the mouth were $\frac{76E4321|1234567}{754321|1234567}$.

There was Class I molar relationship on the left side, Class I canine on the right, and Class I labial segments with slight crowding in the lower incisor region only. The $\overline{6|}$ was not visible, the $\overline{7|}$ had a mesial inclination, and the $\overline{5|}$ a slight distal tilt with spacing between the $\overline{543|}$. The $\underline{6|}$ was over-erupted. Over the $\overline{6|}$ area the mucosa was firm and normal in appearance, with no visible signs of a sinus. Palpation could not elicit

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any sign of a tooth being present. The patient could give no history of pain or discomfort in this region.

Lateral oblique, periapical, and occlusal radiographs were taken (*Figs.* 1, 2), and these showed the $\overline{6|}$ to be present and fully formed. The tooth was normal in appearance, having a mesial inclination and with root apices close to the lower border of the mandible. The mesial root had a distal curve and the distal root a

Fig. 1.—Lateral oblique radiograph showing unerupted $\overline{6|}$.

Fig. 3.—Lateral oblique radiograph of left side for comparison.

mesial curvature. The follicle of the tooth was visible around the crown, and bone covered the top of this. The $\overline{8|}$ crown was showing and in close proximity to the $\overline{7|}$.

A lateral oblique radiograph was taken of the left side for comparison (*Fig.* 3) and both radiographs showed the remaining third molars to be present.

An occlusal view showed no buccal or lingual displacement of the unerupted tooth.

In view of the small amount of bone overlying the unerupted tooth, and the apparent lack of any other obvious cause preventing eruption, it was decided to expose surgically the occlusal surface of the tooth. An obturator was to be fitted for 3 months and the case observed to see if eruption occurred.

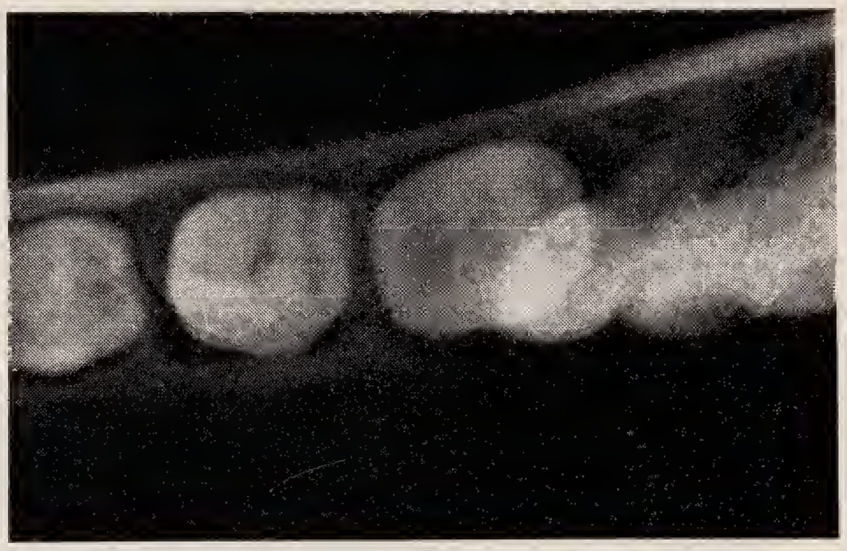

Fig. 2.—Occlusal view of unerupted tooth.

Under local anaesthesia, the periosteum and bone overlying the crown of the tooth were removed. An alginate impression was taken at the time of operation to include the lower arch and area of surgical exposure.

A Whitehead's varnish pack was inserted into the cavity to maintain its patency, and 3 days later an appliance was fitted.

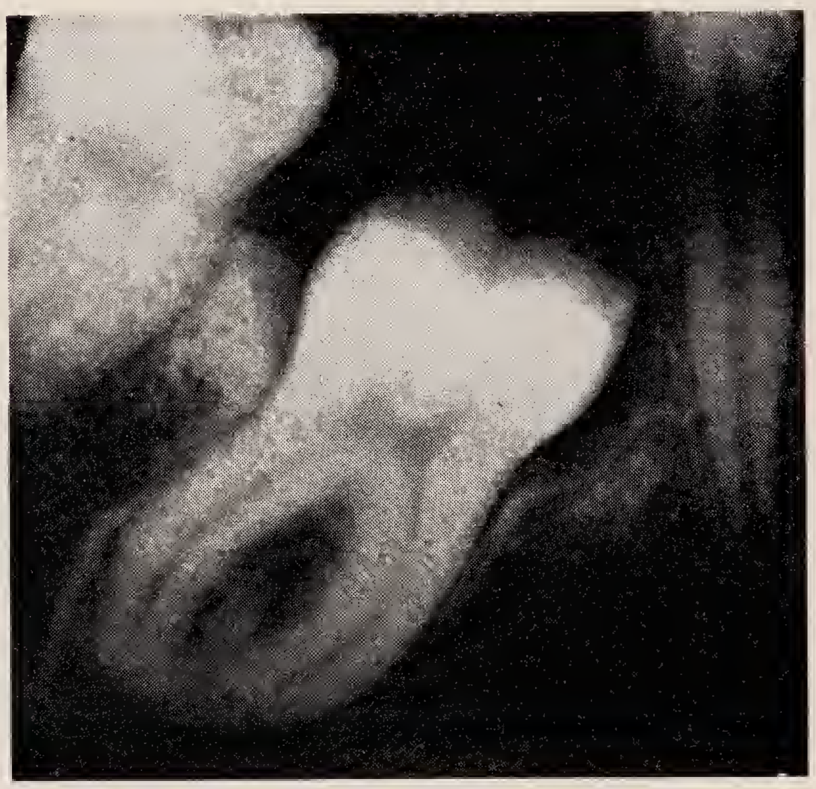

Fig. 4.—Intra-oral radiograph taken 10 weeks post-operatively.

This consisted of a simple removable design, with Adams cribs to the $\overline{74|47}$ for retention, and an acrylic bung which was carried down as far as the occlusal surface of the unerupted tooth.

This appliance was worn continuously, and 10 weeks later a periapical view of the tooth was taken. This confirmed that eruption had commenced (*Fig.* 4).

The appliance was then changed at this stage to a removable screw type to open the space between the $\overline{75}|$. Three months after the fitting of this the disto-lingual and disto-buccal cusps of the tooth were visible in the mouth. Very little progress was made with this appliance in increasing the $\overline{75}|$ space, and after a further 6 weeks it was decided to upright the $\overline{7}|$. To do this a modified 0·7-mm. fixed lingual arch as described by Gould (1959) was constructed. The arch was fitted to bands cemented on to the $\overline{7|6}$.

By June, 1960, sufficient space had been gained by the uprighting of the $\overline{7}|$, and two-thirds of the crown of the $\overline{6}|$, having a mesial tilt, was now visible.

Fig. 5.—Lateral oblique radiograph with lingual arch in situ.

Fig. 7.—Lateral oblique radiograph showing final final position of $\overline{6}|$.

To complete the positioning of the tooth into the arch the same type of appliance was used, this time banding the newly erupted tooth to upright it (*Figs.* 5, 6).

In February, 1961, 20 months after commencement of treatment, the $\overline{6}|$ was in the position shown (*Fig.* 7).

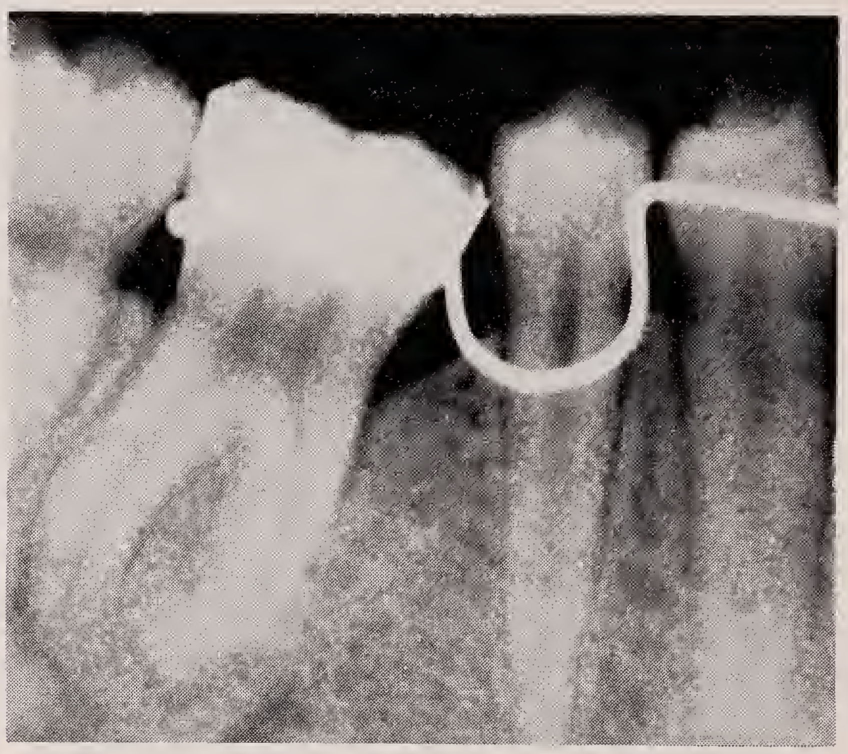

Fig. 6.—Intra-oral radiograph showing details of arch uprighting tooth.

At this stage the patient had to enter another hospital for orthopaedic surgery, and the arch and bands had to be removed at short notice at the request of the anaesthetist.

The patient was seen on one further occasion 9 months later, and this follow-up showed the tooth to be in functional occlusion.

The clinical appearance of the crown of the tooth showed it to be normal in size and shape, but the enamel was whiter in colour and more opaque than the rest of the dentition.

DISCUSSION

The reason for treating this case was that in the opinion of the oral surgery department any future symptoms involving this tooth and its subsequent removal would necessitate an extra-oral approach.

In view of this implication it was felt that there was much to gain and little to lose, and this point was emphasized to both parents and patient, who, after all, were not seeking treatment for this specific problem.

I feel that this case may be described as an unerupted first permanent molar, the aetiology being quite unknown.

I do not believe one can make any judgement at all on one such case, and I simply record it to add to the increasing number of cases where a tooth has for some reason failed to erupt into or maintain its position of

occlusion. However, I do not believe that this tooth was at any time submerged or ankylosed.

SUMMARY

An unerupted first permanent molar with insufficient space was surgically exposed and brought into functional occlusion, thus avoiding possible extensive surgery for its subsequent removal.

Acknowledgements.—I would like to thank Mr. Wilson and Mr. Beresford for permission to publish this case, and Mr. G. R. Seward for the surgery and radiography.

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DISCUSSION

The President said that those present were indebted to Mr. Heffer for bringing forward an extremely interesting case. The question of eruption was a difficult one, about which surprisingly little was known. It seemed that they were on the borderline between the dental anatomist and the orthodontist, and they were not getting very far with the problem at the moment.

Mr. D. F. Glass said that there appeared to be two types of unerupted teeth: submerged teeth and unerupted teeth. Mr. Heffer had managed to make the tooth erupt, in this case, but if it had been submerged, he did not think it would have erupted.

Mr. Glass said he had recently seen submerged teeth where a genetic factor was involved. They occurred in families—mother and daughters—but they were not the same type as Mr. Heffer had shown. The case he himself had reported some years ago had been examined in the pathology department and the report had come after his paper was published; the tooth was actually carious. The tooth had a sinus through to the mouth. He thought that it was actually exposed to the mouth at one stage and got left behind. Mr. Heffer said that his had no connexion with the mouth. There was no proof, except one's judgement, but he had noticed, in the final slide, that it might have been carious. Whether it was carious when it came through or not, Mr. Heffer had not said.

Mr. Glass thought that when teeth were unerupted in cases of cleidocranial dysostosis, heroic attempts to force eruption were not advisable.

Mr. D. A. Dixon agreed with Mr. Glass that there was a genetic factor in such cases. With any eruption problem there were a number of factors; there was the eruption potential of the tooth, the growth of the face in which the tooth was erupting, and the different types of facial form; this latter aspect may show a connexion with genetic factors.

He did not feel that ankylosis was a prime cause. It occurred quite frequently, but he thought it was a secondary feature which followed on the failure of the tooth to erupt. It did not necessarily mean the tooth would not erupt later because there would be resorption and deposition going on constantly around the root of the tooth, and with this change in the tissues it could free itself. If normal deciduous teeth were extracted, and histologically examined, one was occasionally found to be ankylosed in any case.

He congratulated Mr. Heffer on his result. He himself had not had a great success; perhaps the free exposure was a great help. Had Mr. Heffer had trouble with his anchorage? He found, when he tried to move such a tooth, that everything else moved. Some people said that it helped things to give the tooth a slight rock. He did not think impaction against a deciduous molar was the only cause, but it could occur, and was one cause of a condition of which we still have little knowledge.

Mr. A. J. Walpole Day asked Mr. Heffer why he thought the tooth erupted. Did he think that the mechanical irritation of the operation plus removal of the obstruction had caused congestion in the periapical vessels?

In his department, they tended to leave their initial pack in for at least a month. It was found, when the packing was taken out, that the unerupted tooth erupted much faster than normally.

It was frequently noticed that the enamel on the unerupted tooth was deficient, often looking milky and opaque, and it was quite frequently liable to caries. In some cases, where supernumeraries had been removed very early to facilitate eruption of the unerupted centrals, the latter teeth were a bit opaque so that it did not appear to be anything to do with long retention of the tooth.

Professor D. P. Walther asked how many failures Mr. Heffer had had. He himself had had one or two successes, but many, many failures, and he could not distinguish which one would be a success and which would not.

Mr. P. H. Burke said that the crux of the problem was the successful prognosis for eruption of the unerupted tooth. There had been a large follicle around the tooth. He looked upon that as a mechanism of a tooth which had a good eruptive potential, but which was delayed. Did Mr. Heffer measure the rate of movement of the tooth? There were many other factors which came into the prognosis for eruption, with particular reference to the formation of roots. From those, he would have expected that the eruptive potential of this particular tooth was poor.

Mr. J. H. Gardiner asked for further details of the tissue overlying the occlusal surface of the first permanent molar. Stoy, of Belfast, had shown that in cases where the presence of a supernumerary tooth was associated with lack of eruption of a central incisor, there was no connexion between the two teeth. Moreover, in such cases, if the supernumerary was left, but the tissue overlying the central incisor removed, the latter tooth

erupted. Had Mr. Heffer any observations to make in that direction?

Mr. H. G. Watkin said it reminded him of a case he had had about thirty-five years ago, of a boy aged 12 years who had come into his surgery with a discharge in the region of the root of the first permanent molar. The local hospital had been treating him for osteomyelitis and scraping the bone. He had taken an X-ray and found that the first permanent molar was impacted, dead, and discharging. He had removed the tooth, and the condition had quickly resolved.

Mr. Heffer, in reply, said he was interested in Mr. Glass's observation because he had particularly noted his paper on the unerupted tooth. There appeared, as far as one could tell, no evidence of a sinus or any connexion with the mouth to the unerupted tooth. He could not say more.

He thought that Mr. Dixon had answered his own question about anchorage. Had the tooth been ankylosed there would have been evidence of some movement of the anchorage teeth, but this was not so. He did not think it was ankylosed, and all evidence pointed to the fact that it was not.

He thanked Mr. Walpole Day for his remarks. He did not know how the tooth erupted. Perhaps he could suggest that the eruptive process initiated by the exposure might bear little resemblance to the normal eruptive process of a tooth where root formation continued at the same time.

On the number of failures, he assured Professor Walther that he had had none at all! One saw many cases of submerged deciduous and permanent molars. He did not know of anyone who had tried to pull these up. The feeling seemed to be that in general they submerged until they were swallowed up, and one hoped to extract them before that happened.

On the question of the tissue over the unerupted tooth, this was not sent for a pathological report as it was thought it would contain loose connective tissue and little else significant. He would say that the removal of the tissue with good adequate exposure would most likely remove one of the causative factors preventing eruption.

A COMPARISON OF THE MECHANICS AND EFFICIENCY OF 21 ORTHODONTIC EXPANSION SCREWS

By S. HAYNES, B.CH.D., F.D.S. R.C.S., D.ORTH., and D. JACKSON, D.D.S., M.D.S.
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Although orthodontic expansion screws have been in use for over half a century, it is not widely known that many different types are available, and that their mechanical properties differ sufficiently to affect their clinical usage. Standard British textbooks on orthodontics do not mention these basic considerations and demonstrate a considerable variance of opinion concerning the mechanics and usage of screw appliances. White, Gardiner, and Leighton (1954) give the distance moved per quarter turn as 0·18–0·2 mm., but make no reference to any particular screw, or the rate at which it should be turned. Dickson (1959) recommends that both 'rigid' and 'spring-tension' types be turned at the same rate, but advises a quarter turn twice weekly for lateral expansion and once weekly for retraction and proclination. Adams (1957) considers that the amount of expansion per quarter turn is of no clinical significance and that a screw should be activated whenever the sensation of tension has disappeared from the teeth. Walther (1960) states that the amount of movement per quarter turn is approximately 0·18 mm., and suggests a rate of twice weekly for children and once weekly for adults, although again no particular type of screw is specified. Tulley and Campbell (1960) advise turning expansion screws once or twice weekly, but give no further information regarding either the type of screw or distance moved per turn. English texts by continental authors also vary with reference to expansion screws. Haupl, Grossman, and Clarkson (1952) refer to a particular type of Fischer screw not universally available. This screw, they state, moves 0·16 mm. per quarter turn and they advise weekly activation to a maximum of 40 weeks. Lundström (1960) only briefly refers to the clinical use of expansion screws, but no information is given regarding either function or usage. Hotz (1961) states that spring-loaded screws have no inherent advantages over rigid ones, and although reference is made to the Fischer screw no further information is given concerning either its mechanical properties or clinical application.

The above references to such a popular orthodontic mechanism illustrate the need for additional information, and for this reason a small investigation into the mechanics of 21 different types was undertaken. The results are presented herewith together with a brief summary of the chronological development of expansion screws.

The earliest British reference to orthodontic screws was made by Badcock (1911), but they had previously been referred to by Robin (1902). In 1919 Nord (1928, 1961) commenced to use his own type of screw, which was simpler in design than Badcock's. The Fischer screw was first presented in 1934, this being manufactured by Franz Fischer, a Viennese engineer, to the specification of Schwartz and Petrick of Vienna. This screw was of much better design than those of Badcock and Nord, and became the basis of many which were subsequently introduced. In 1945 the Glenross series was made available, and these were followed by the Hausser screw in 1949, designed by Hausser of Hamburg and marketed by the German firm Dentaurum. The Ash Parallel was first manufactured in 1954, and in 1957 Wipla introduced an extensive range which consisted of 2 screws of the Hausser pattern and 4 of the modified basic Fischer type. In the same year, the Orthotecknick screw was introduced by Heath (1958) of Melbourne. This was designed for use on patients having minimum supervision of orthodontic treatment, and differs completely from the Fischer types. Hawley Russell's first series was marketed in 1959, and consisted of one Schwartz (999, *Fig.* 3) and two Fischer screws (777 and 666, *Fig.* 3). Another range, Double Anchor and Skeleton

Given at the Edinburgh meeting held on 11 May, 1962.

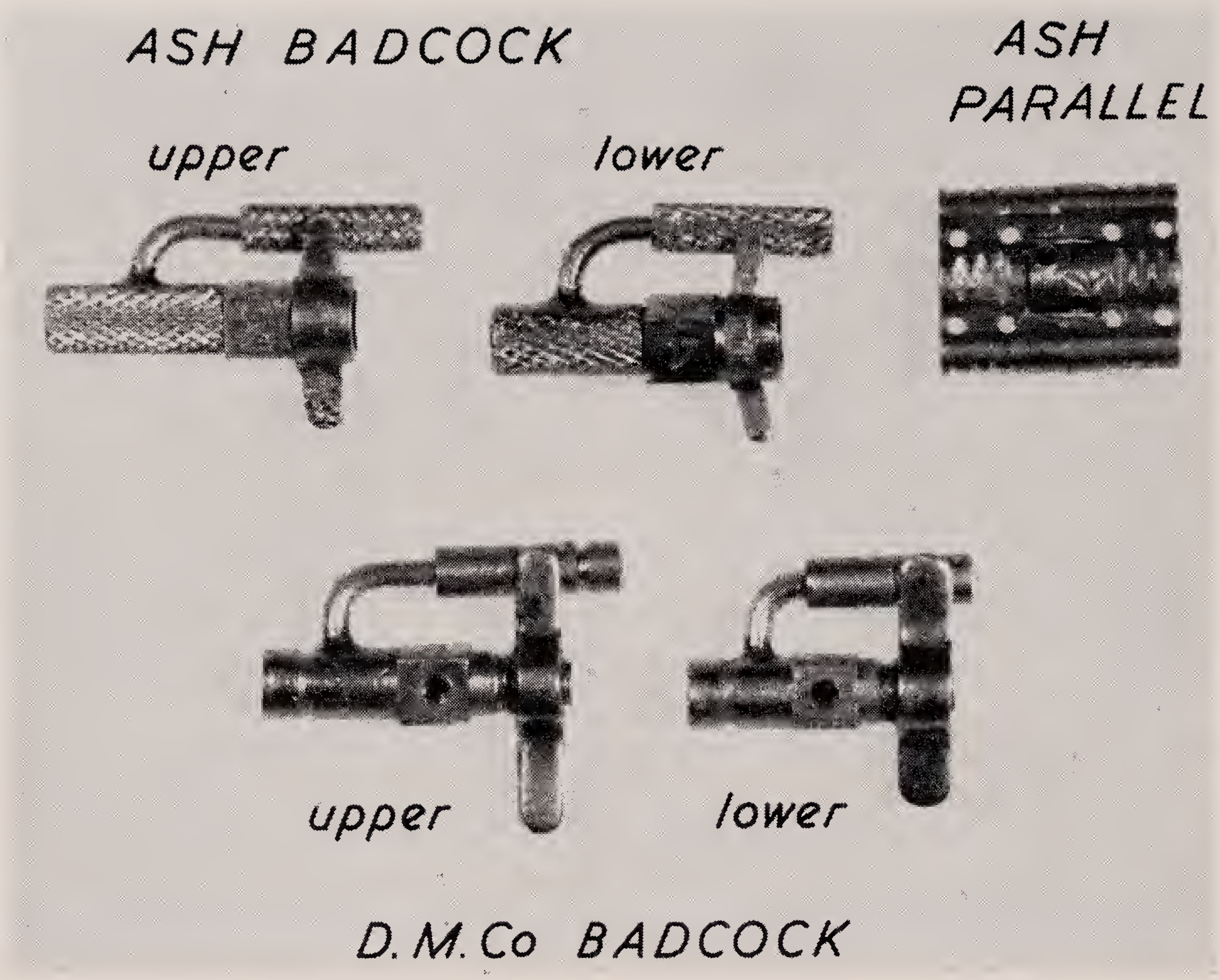

Fig. 1.—Types of screw manufactured by Claudius Ash & Co. Ltd., and the Dental Manufacturing Co. Ltd.

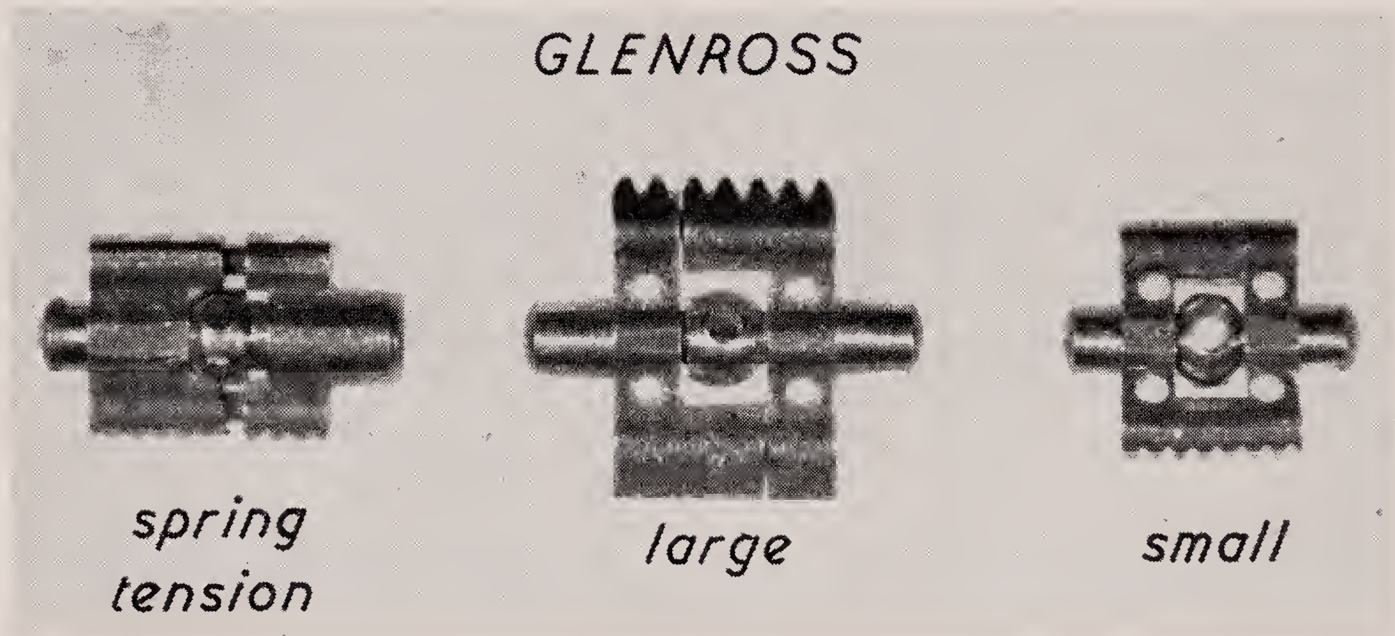

Fig. 2.—Types of screw manufactured by Glenross Ltd.

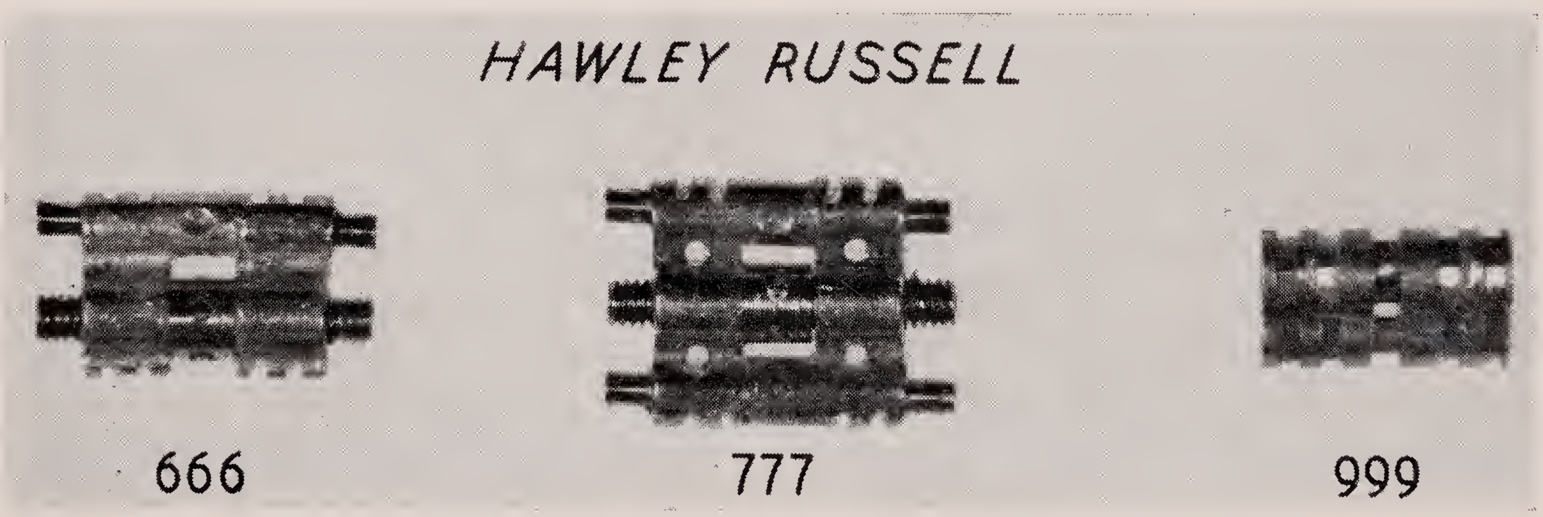

Fig. 3.—First series of screws manufactured by Hawley Russell Ltd.

types, was introduced in 1961. Other screws have recently been introduced, amongst which are 3 by Lomberg of Amsterdam, 14 by Rocky Mountain Products, U.S.A., and 1 by Absvenska Dental Instruments of Stockholm. The latter is a small spring-loaded screw which is only suitable for the movement of single teeth.

To date, no fewer than 48 different types of screws have been identified, but the situation is complicated by the fact that several manufacturers produce slightly modified versions of the same generic Fischer type. In this report, only those screws which are readily obtainable in the United Kingdom are considered, it being intended to report on the others at some future date.

INVESTIGATION

1. Material.—The screws studied were grouped according to manufacturer as follows:—

a. Ash: Badcock upper and lower, and the Ash Parallel (*Fig.* 1).

b. Dental Manufacturing Co. Ltd.: Badcock upper and lower (*Fig.* 1).

c. Glenross: Small, large, and spring tension (*Fig.* 2).

d. Hawley Russell: Fischer patterns 666 and 777, Schwartz pattern 999 (*Fig.* 3). Skeleton patterns 222 and 333, and double anchor patterns 662 and 773 (*Fig.* 4).

e. Wipla: Hausser spring tension patterns 623 and 624, and the Fischer types 627, 628, 629, and 630 (*Fig.* 5).

2. Data Obtained.—The data obtained from each screw were maximum length, width, and

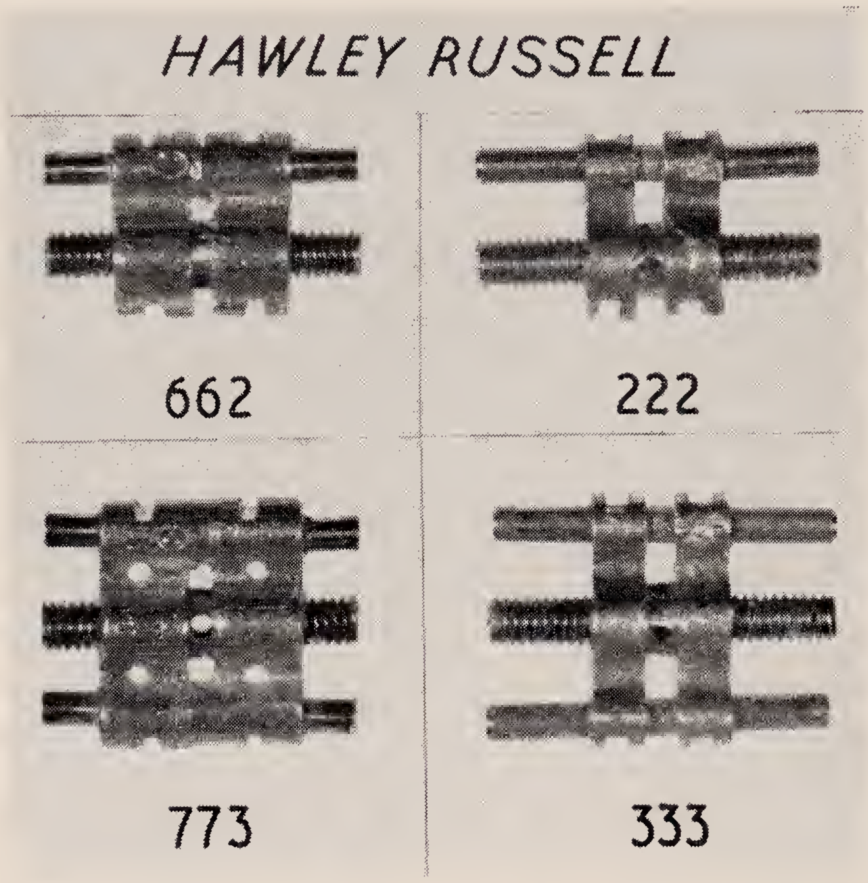

Fig. 4.—Second series of screws manufactured by Hawley Russell Ltd.

thickness (from which the volume was calculated), together with the absolute and stable traverse. These latter measurements were determined together with the number of

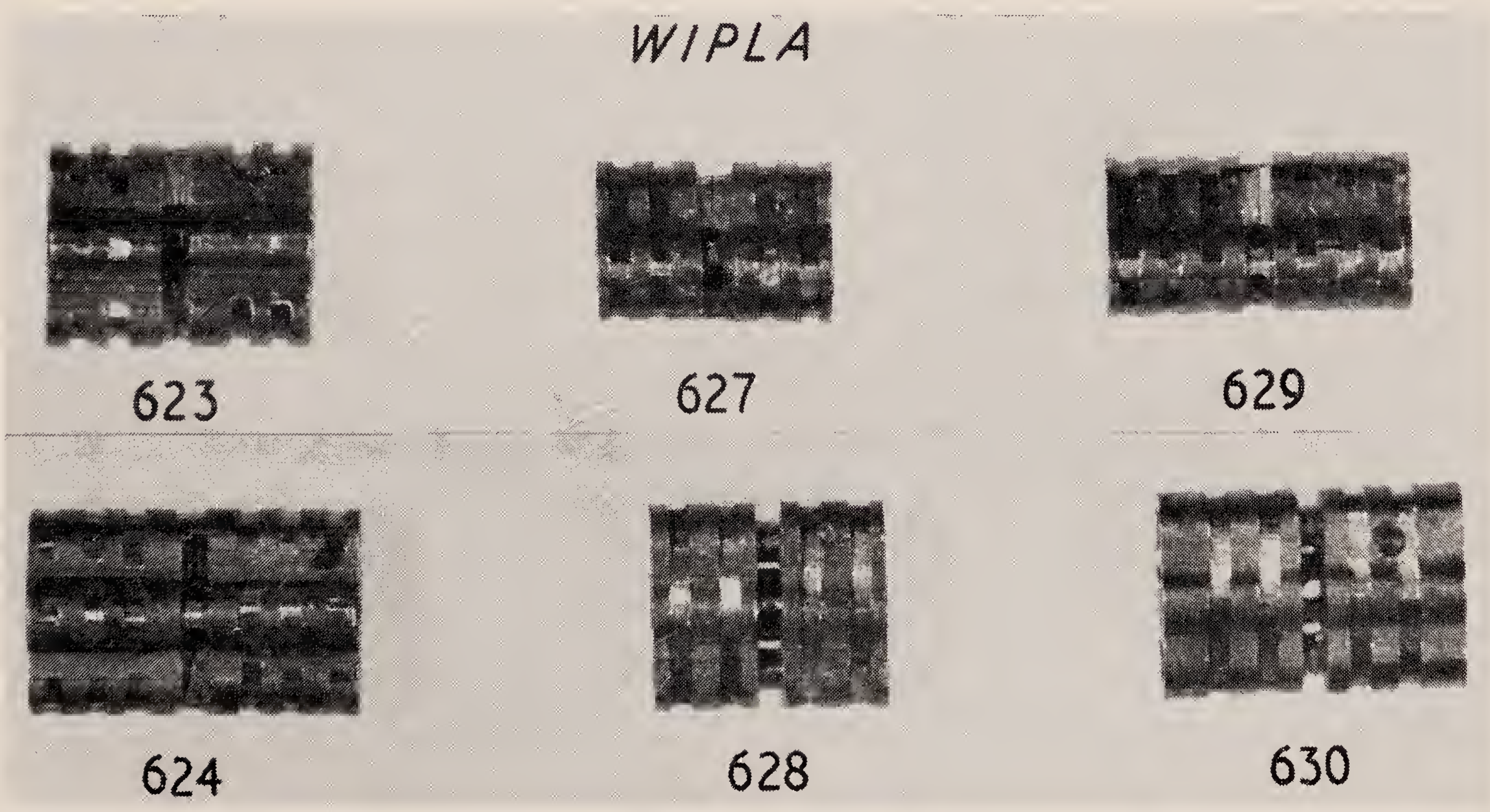

Fig. 5.—Types of screw manufactured by Wipla Ltd.

14*

quarter turns of each screw which were required to reach these respective points. The traverse per quarter turn was then obtained by correlating the absolute traverse with the number of quarter turns necessary to achieve it.

3. Methods.—Six screws of each type were randomly chosen and measured to the nearest 0·01 mm. by means of a metric micrometer. The procedure was repeated three times and an average value obtained for each factor required. Thus the final figures relative to each type of screw represent the average of 18 readings in each case. Absolute traverse was the maximum traverse beyond which the screw ceased to be an integral unit by virtue of dissociation of either the screw from its housing or guide pins from their sleeves. This was the difference between the length closed and length opened as determined by the distance between end faces. Stable traverse was the maximum traverse compatible with stability, beyond which there was such vertical or lateral play as to make the screw inefficient in clinical use. This measurement was obtained by the same procedure as that used to determine absolute traverse. The determination of the end-point of stable traverse was purely subjective. The percentage ratio of stable to absolute traverse was taken to be the efficiency of the screw. In the determination of the volume of each type of screw, the irregularities of contour were disregarded, since the overall measurements are the main factors affecting their bulk, and hence clinical application.

Table I.—DATA PERTAINING TO THE DIMENSIONS OF 21 ORTHODONTIC SCREWS

TYPE OF SCREW	OVERALL MEASUREMENT				
	Length	Width	Thickness	Surface Area	Volume
	mm.	mm.	mm.	$mm.^2$	$mm.^3$
Ash					
★ Badcock upper	14·3	10·8	4·0	154	625
★ Badcock lower	13·4	10·7	4·0	144	584
Parallel	11·2	8·6	3·2	95	311
D.M. Co.					
★ Badcock upper	14·2	12·9	3·6	183	665
★ Badcock lower	12·4	11·6	3·5	144	514
Glenross					
Small	11·9	9·6	3·9	115	445
Large	15·9	13·0	3·9	208	818
Spring-tension	14·7	8·1	3·9	120	468
Hawley Russell					
★ 999 Schwartz	10·1	5·6	3·2	56	183
777 Fischer	14·1	9·8	3·4	138	469
★ 666 Fischer	14·3	7·3	3·3	104	350
★ 222 Skeleton	14·3	7·3	3·3	104	340
333 Skeleton	14·2	10·2	3·4	145	498
★ 662 Double anchor	13·0	7·4	3·3	97	315
773 Double anchor	12·7	9·9	3·3	127	425
Wipla					
623 Hausser spring tension	11·3	8·7	4·0	98	395
624 Hausser spring tension	14·3	8·6	4·1	123	505
★ 627 Fischer	10·1	6·7	3·9	68	272
628 Fischer	9·9	8·6	3·9	85	340
★ 629 Fischer	12·9	6·7	4·0	87	351
630 Fischer	12·9	8·6	4·0	112	447

★ Indicates screws with single guide-pins

RESULTS

1. Overall Measurements (*Table I*).—The screw of shortest overall length was Wipla 628 (9·9 mm.) and the longest the Glenross large (15·9 mm.). The majority (15) of the screws examined had an overall length within the range of 12–15 mm.

2. Absolute Traverse (*Table II*).—There was found to be a considerable range of absolute traverse, this being from 3·4 mm. (Glenross spring tension) to 8·0 mm. (Hawley Russell 777).

3. Traverse per Quarter Turn (*Table II*).—Values for this factor were found to be in two

Table II.—The Absolute Traverse, Number of Quarter Turns, and Traverse of a Quarter Turn in 21 Orthodontic Screws

Type of Screw	Length			Traverse	
	Closed	Opened	No. of Quarter Turns	Absolute	Per Quarter Turn
	mm.	mm.		mm.	mm.
Ash					
★ Badcock upper	14·3	19·9	51	5·6	0·11
★ Badcock lower	13·4	17·5	37	4·1	0·11
Parallel	11·2	16·2	23	5·0	0·21
D.M. Co.					
★ Badcock upper	14·2	19·3	48	5·1	0·11
★ Badcock lower	12·4	16·5	39	4·1	0·11
Glenross					
Small	11·9	15·7	17	3·8	0·21
Large	15·9	20·5	21	4·6	0·21
Spring-tension	14·7	18·1	31	3·4	0·11
Hawley Russell					
★ 999 Schwartz	10·0	14·1	20	4·1	0·20
777 Fischer	9·9	17·9	40	8·0	0·20
★ 666 Fischer	10·1	17·9	39	7·7	0·20
★ 222 Skeleton	5·5	11·7	32	6·2	0·20
333 Skeleton	5·5	11·8	33	6·3	0·19
★ 662 Double anchor	7·2	13·5	31	6·3	0·20
773 Double anchor	8·2	14·6	32	6·4	0·20
Wipla					
623 Hausser spring-tension	11·3	15·8	27	4·5	0·17
624 Hausser spring-tension	14·3	20·2	35	5·9	0·17
★ 627 Fischer	10·1	14·6	21	4·5	0·21
628 Fischer	9·9	13·7	17	3·8	0·21
★ 629 Fischer	12·9	19·0	28	6·1	0·22
630 Fischer	12·9	18·2	24	5·2	0·22

★ Indicates screws with single guide-pins.

There was also considerable difference with respect to width, which ranged from 5·6 mm. (Hawley Russell 999) to 13·0 mm. (Glenross large). The commonest width was found to be between 6 and 9 mm.

In contrast to the above findings, there was very little difference in thickness, almost all screws being within the range 3·2–4·0 mm. The thinnest screws were the Hawley Russell 999 and the Ash Parallel (3·2 mm.); the thickest was the Wipla 624 (4·1 mm.).

main categories. Five screws had a value of 0·1 mm., whilst 14 had a value of 0·2 mm. Variation about these figures was extremely small, and within the range of experimental error. The remaining 2 screws (Wipla 623 and 624) are excluded from these two main groups since the value obtained for each was 0·17 mm.

4. Stable Traverse and Relative Efficiency (*Table III*).—The stable traverse for the majority of screws was found to be in the range 3–5 mm., but for some it was of a very

low order, i.e., less than 3 mm. Efficiency was progressively lost if the screw was turned beyond the point of stable traverse. The range of efficiency extended from 47 per cent (Hawley Russell 662) to 100 per cent (Glenross large, Wipla 630, and Hawley Russell 999 and 773). The majority had values exceeding 80 per cent.

Coefficients of variation were least for Wipla 630 and highest for Hawley Russell 666.

DISCUSSION

The desirable qualities of an orthodontic screw are easily defined. It should possess a high mechanical efficiency (in the context of the previously stated definition), minimal bulk and variability, and a stable traverse of at least 4 mm. If bulk was dependent on traverse, and all other factors were equal, then choice would depend mainly on amount of movement required. This is not universally true since that with the least bulk (Hawley Russell 999) has almost the same traverse as that which possesses most (Glenross large).

Most orthodontic movements required are 4 mm. or less, and for such a range it would

Table III.—The Maximum Amount of Traverse compatible with Stability in 21 Orthodontic Screws, together with an Index of their Efficiency

Type of Screw	Stable Traverse	No. of Quarter Turns compatible with Stability	Efficiency
	mm.		per cent
Ash			
* Badcock upper	2·9	26	53
* Badcock lower	2·7	25	66
Parallel	4·3	20	85
D.M. Co.			
* Badcock upper	3·8	35	74
* Badcock lower	3·0	28	73
Glenross			
Small	3·3	17	98
Large	4·5	21	100
Spring-tension	3·0	27	83
Hawley Russell			
* 999 Schwartz	4·1	20	100
777 Fischer	7·9	39	99
* 666 Fischer	7·5	37	98
* 222 Skeleton	5·8	28	93
333 Skeleton	5·9	30	93
* 662 Double anchor	2·9	15	47
773 Double anchor	6·4	31	100
Wipla			
623 Hausser spring-tension	3·2	22	87
624 Hausser spring-tension	4·1	24	69
* 627 Fischer	4·1	19	91
628 Fischer	3·4	16	90
* 629 Fischer	5·5	25	90
630 Fischer	5·2	24	100

* Indicates screws with single guide-pins.

5. Individual Screw Type Variations (*Table IV*).—Variation of absolute traverse between individual screw types was less than 0·5 mm. for the majority examined. Least variability occurred in the Wipla 630 (0·1 mm). and most in the Hawley Russell 666 (2·3 mm.). The majority of screw types were consistent in that the number of turns required to achieve absolute traverse varied by less than 2, and for five of these variability was less than 1.

appear that the Hawley Russell 999 is the screw of choice; it was the least bulky screw examined (183 mm.^{3}), had a high mechanical efficiency (100 per cent), and a low coefficient of variation. For movements exceeding 4 mm. the Hawley Russell 666 is most suitable, since it has a low bulk (350 mm.^{3}), high efficiency (98 per cent), and a long range (8 mm. approximately). The coefficient of variation is high (10 per cent), but relatively unimportant for a screw having this range of action. If a range of action exceeding 4 mm. is required and the overall length of this screw (14·3 mm.) cannot be accommodated, the next most suitable would be the Wipla 629. Although this has a similar bulk and range to the Hawley Russell 222 it is to be preferred to the latter since it is both shorter and narrower.

Efficiency was found to be associated with the clearance between the moving parts, i.e., the difference between the effective diameters of screw and nut, and guide pins and sleeves respectively. This finding suggested that a second guide pin did not necessarily increase efficiency if the machining was of high quality, as very little variation was found when basically similar screws were available in single or double guide pin form. This is seen if Hawley Russell 666 and 222 are compared with 777 and 333 respectively.

Spring-tension screws were found to be less efficient than rigid ones, and had a disproportionate increase in bulk for the stable traverse obtained. In all types the amount of screw thread engaged by the nut was less than that in rigid screws. In the Glenross type the

Table IV.—Variability of Absolute Traverse and Number of Quarter Turns found in 21 Types of Orthodontic Screws; Data for each Screw obtained from a Sample Size of Six

Type of Screw	Traverse			No. of Quarter Turns		
	Range	Mean	Coefficient of Variation	Range	Mean	Coefficient of Variation
	mm.	mm.	per cent			per cent
Ash						
⋆ Badcock upper	5·3–5·7	5·6	2·95	50·0–53·0	51·5	2·27
⋆ Badcock lower	3·9–4·2	4·1	3·47	36·0–38·6	37·2	2·92
Parallel	4·8–5·2	5·0	3·64	23·0–24·0	23·4	2·07
D.M. Co.						
⋆ Badcock upper	4·9–5·2	5·1	2·32	46·6–52·6	48·6	4·61
⋆ Badcock lower	4·0–4·2	4·1	2·28	38·0–40·0	38·9	2·08
Glenross						
Small	3·6–3·8	3·7	2·53	17·0–18·0	17·5	2·55
Large	4·4–4·7	4·6	2·29	20·6–22·0	21·3	3·58
Spring tension	3·1–3·6	3·3	6·85	29·0–33·0	31·3	5·06
Hawley Russell						
⋆ 999 Schwartz	4·0–4·2	4·1	3·46	20·3–21·3	20·6	1·71
777 } Fischer	7·9–8·2	8·0	1·24	39·3–41·3	40·0	2·46
⋆ 666 } Fischer	6·6–8·9	7·8	10·77	32·6–44·3	38·9	10·39
⋆ 222 } Skeleton	6·0–6·4	6·2	1·75	30·6–32·3	31·6	2·31
333 } Skeleton	5·8–6·5	6·2	5·86	30·0–33·3	31·7	3·57
⋆ 662 } Double anchor	6·0–6·6	6·2	6·06	30·0–32·3	31·1	3·46
773 } Double anchor	6·1–6·7	6·4	3·44	30·3–34·0	32·0	5·07
Wipla						
623 } Hausser Spring-tension	4·3–4·7	4·5	3·24	26·0–27·6	27·1	2·79
624 } Hausser Spring-tension	5·0–6·3	5·6	7·31	29·5–37·3	33·0	8·35
⋆ 627 } Fischer	4·3–4·7	4·5	4·96	20·3–22·0	21·0	2·60
628 } Fischer	3·6–3·8	3·7	6·55	17·0–18·0	17·4	3·58
⋆ 629 } Fischer	5·9–6·3	6·1	2·84	27·0–29·0	27·6	3·81
630 } Fischer	5·1–5·2	5·2	4·71	24·0–24·3	24·0	4·17

⋆ Indicates screws with single guide-pins.

spring was sealed in one housing and the screw turned within the other. The Hausser screw incorporated a spring at each and. It encircled the major portion of the thread, and had its outer end attached to the housing and inner end attached to a nut of much reduced size.

The materials used did not significantly influence the efficiency of the screws, since both high and low values were obtained for the various metals employed. Screws constructed wholly of nickel-based alloy compared favourably with others of similar design which were made of stainless steel throughout, or composed of stainless steel guide-pins with housings of either silver or nickel alloy.

This investigation has enabled certain practical recommendations to be made. These

Fig. 6.—Screws recommended and considered to be of greatest value for routine orthodontic practice.

Table V.—Practical Recommendations concerning the Use of 21 Orthodontic Screws

Type of Screw	No. Turns per Week	No. of Quarter Turns	Stable Traverse obtained to nearest half mm.
Ash			
⋆ Badcock upper	2	26	3
⋆ Badcock lower	2	25	2·5
Parallel	1	20	4·5
D.M. Co.			
⋆ Badcock upper	2	35	4
⋆ Badcock lower	2	28	3
Glenross			
Small	1	17	3·5
Large	1	21	4·5
Spring-tension	2	27	3
Hawley Russell			
⋆ 999 Schwartz	1	20	4
777 Fischer	1	39	8
⋆ 666 Fischer	1	37	7·5
⋆ 222 Skeleton	1	28	6
333 Skeleton	1	30	6
⋆ 662 Double anchor	1	15	3
773 Double anchor	1	31	6·5
Wipla			
623 Hausser Spring-tension	1	21	3
624 Hausser Spring-tension	1	24	4
⋆ 627 Fischer	1	19	4
628 Fischer	1	15	3·5
⋆ 629 Fischer	1	25	5·5
630 Fischer	1	24	5

⋆ Indicates screws with single guide-pins.

are shown in *Table V* and are based on the use of simple intra-maxillary anchorage in all cases. The rate of turning is related to an estimated tooth movement of 0·2 mm. per week, and the majority of screws are activated once or twice weekly, depending on their respective movements per quarter turn. Wipla screws 623 and 624 do not fall into either category, and would require turning every sixth day if they were to maintain a similar rate of progress. This procedure, however, would be both unreliable and inconvenient, and hence it is advised that these screws are turned once per week. The screws of most value were found to be Hawley Russell 999 and 666, and Wipla 629. These are illustrated in *Fig.* 6.

SUMMARY

In this investigation the physical and mechanical attributes of 21 orthodontic screws have been assessed. The data obtained have enabled certain recommendations to be made with regard to selection and usage. The Hawley Russell 999 is the screw of choice for movements not exceeding 4·0 mm. and the Hawley Russell 666 most satisfactory for movements greater than this distance. The latter screw, however, is relatively long, and where the curvature of the arch prevents its satisfactory alinement it is suggested that the Wipla 629 be used.

Each screw recommended moves 0·2 mm. per quarter turn and activation should not exceed one turn per week. The period of effective use and number of weekly turns is 20 for the Hawley Russell 999, 37 for the Hawley Russell 666, and 25 for the Wipla 629.

Recommendations are based entirely on intrinsic mechanical and physical considerations and not on economic factors, since these are subject to fluctuation and personal assessment.

Acknowledgements.—The authors wish to express their gratitude to Miss A. Cooper for statistical and secretarial assistance, and to Mr. H. Grayshon Lumby, M.S.I.A., N.D.D., and Mr. L. Jepson, A.I.B.P., A.I.S.T., for assistance with the illustrations.

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DISCUSSION

Dr. B. G. Hopkin said that first, he wished to add a little to what Mr. Haynes had said of the history of the screw in orthodontics, which first appeared in the form of a screw jack.

According to Farrer, 1876, who interviewed both claimants, the kudos for the successful introduction of the screw jack around 1850 went jointly to a Dr. Dwinelle of America and Charles Gaine of Bath.

The introduction of vulcanite in the fifties also helped in developing the use of screw forces, but the principal form seemed to have been the jack screw with the base attached to a band or embedded in a plate with the free end of various shapes pressing against the individual teeth.

The problem was further simplified by the lateral expansion screw of Angle which had all the basic elements of the modern screw, a centre nut and right- and left-hand threads.

Despite that, the screw seemed to have declined in favour to such an extent that Jackson, in his 1907 text, mentioned screws but to condemn them, and it appeared that it was with the introduction of the Glenross screw that the screw came into its own again as one of the most versatile weapons in the orthodontist's armoury, although it had never entirely gone out of favour.

With regard to Mr. Haynes's findings, he was in agreement with the recommendation of the Hawley 999, and last year his department had used it so much that they had received a very courteous but plaintive letter from Hawley Russell explaining that they did sell other patterns of screw. One disadvantage of Hawley Russell compared with Glenross was that the key of the latter,

with its limiting collar, was much easier for the patients to use.

What he thought was the most important point in Mr. Haynes's paper was the recommendation of one quarter turn a week or 0·2 mm. expansion.

He would be interested to know the reasons for Mr. Haynes's recommendation of one turn a week. Was it clinical experience or experimental findings that prompted that view? Reitan's monograph on initial tissue reactions gave some information regarding the effects on the tissues of the speed and amount of expansion in human subjects. His findings were that relatively frequent expansion—every 4 days through a minor distance (0·1 mm.)—was preferable to heavy expansion (0·4 mm.) every 6 to 8 days, even if the latter was performed at greater intervals of time.

He suggested that that was a field where Mr. Haynes's work might be extended. He knew the difficulties of experimenting with human subjects, but thought it would be useful to have further evidence on that point.

Mr. B. C. Leighton said that there were two important aspects of the use of intermittent forces: one was the frequency with which adjustment was made and the other was the amount of adjustment made at each time. The second seemed to him to be very important. The younger the patient, the better the screw pressure was tolerated. He was sure that that was due to the greater thickness of peridontal membrane in the younger patient. The solution was to reduce the amount that the screw was opened each time. More information was needed, particularly from histologists, on the rate of reaction of the periodontal membrane to the force.

Clinically, the stiffness and symptoms of screw pressure wore off within 12 hours of adjusting the screw, so it would appear that any time after 12 hours would be a good time to make that adjustment. However, clinical signs could be deceptive.

Dr. J. R. E. Mills commented on the differences in the variations between different samples of the Hawley Russell 666 and 777 screws, as shown in *Table IV*. Was this due to a single 666 screw being abnormally short, or was the variation general?

Mr. A. F. D. Shapland asked if two turns per week meant whole turns or quarter turns.

Mr. Haynes said it should be two quarter turns.

Mr. E. J. R. Bird asked if Mr. Haynes would go into the question of the efficiency of keys as well as the efficiency of the apparatus. He had tried an Ash Parallel a few years ago and had found that the key was so fine that it was easy to break, whereas the Glenross had a nice thick key.

He cut one of the small sleeves and guide-pins off the small Glenross in certain cases. Had Mr. Haynes investigated that?

Mr. J. H. Gardiner made a plea for patients. The average patient, if he was told any variation less or greater than once per week, got a little confused. He suspected that they worked out the screw turning according to some weekly family event.

Mr. H. G. Watkin asked when Mr. Haynes used a screw. He personally seldom found expanded arches to be stable.

Mr. W. Frankland said he was sure many members would be interested to know which was the 'best buy'.

Mr. Haynes, replying to the discussion, said that the Hawley Russell key could certainly be improved, as the absence of a shoulder sometimes gave rise to difficulties. A simple modification was to bend the key about 3 mm. from the end, and thus prevent the patient from inserting it too far.

Both Dr. Hopkin and Mr. Leighton had asked for the reasons for advocating a specific number of turns per week. The main consideration here was clinical experience. The most reliable rate of tooth movement by screws was approximately 0·2 mm. per week, and this was a little more than the width of the periodontal membrane. If a screw was activated beyond this rate, there was always the chance that the appliance would not be 'pushed right homc'. Therefore, one must accept that treatment time with screw appliances is longer than that for removable appliances in which springs are the active components, but none the less they had the inherent advantage of stability. In certain cases they were the removable appliance of choice, e.g., if first permanent molars had been lost and immediate retraction of premolars was necessary.

Dr. Mills had asked about coefficients of variation for Hawley Russell 777 and 666. The latter screw showed most variation and the range of the six screws examined was 6·5–8·9 mm.

Mr. Bird had mentioned the technique of removing one guide pin and sleeve from the Glenross small screw as a means of reducing bulk. However, since this screw only had a stable traverse of 3·3 mm. and was thicker than the Hawley Russell 999 he (Mr. Haynes) had decided to discontinue its use, and, therefore, had not studied the extent to which stable traverse was affected by such a modification. Mr. Watkin had raised the general question of where to use screws. They were useful for most types of tooth movement, especially retraction and proclination.

The cost of screws had been raised by Mr. Frankland and this was of basic importance to the practitioner. The Wipla screws were the most expensive of those examined and varied from 21s. 6d. to 28s. 6d. (Wipla 623 and 624). The cost of the other screws investigated was approximately 8s. but Hawley Russell screws varied from 6s. 6d. (666 and 777) to 10s. (999).

CASES TREATED BY EXPANSION APPLIANCE

By MARGARET N. MILLER, L.D.S. (GLASG.)

In the cases to be discussed, treatment by expansion appliance was used to correct certain types of cross-bite.

Cross-bite may be found in both temporary and permanent dentition, but, according to the statistical comparisons made by Korkhaus in 1926, it seems to occur more commonly in the temporary dentition. The figures at that time showed 39 cases per 1000 at 6 years of age, and 16 per 1000 at the age of 14 years. From this, one can conclude that self-correction does in fact occur in certain types of cross-bite. The reasons for this may be attributed to the natural attrition of the temporary dentition, or to the loss or extraction of temporary teeth, where these were found to be interfering with normal closure. Natural correction can also be due to the molars and premolars erupting in a wider arch than that of the temporary molars.

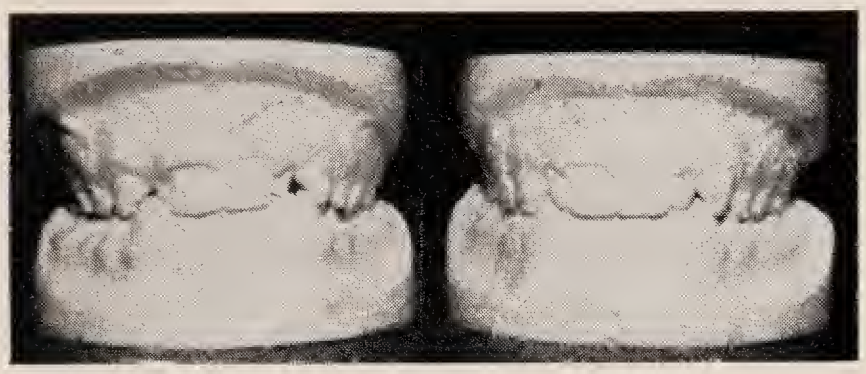

Fig. 1.—Models with peg-shaped $\underline{2|2}$ and deviation of upper centrals to right. Before and after treatment.

Although cross-bite is most often found in the molar and premolar region, it may, in some cases, extend as far forward as the centrals. The condition may also be local where one tooth only may be involved, due possibly to the early loss of a deciduous molar, when the subsequent forward drift of the permanent molar causes a lack of space for the premolar in the arch. Cross-bite may also be due to a narrowness of the upper arch on one or both sides or to a lingual inclination of the cusps of the molars and premolars, but this can be accepted provided there is a good functional dentition.

There remains, however, the type of cross-bite which is associated with the lateral deviation of the mandible in the path of closure. This deviation of the mandible sometimes reveals a facial asymmetry which can be distressing to the parents if observed. Deviation of the mandible may be a causative factor in some of the disorders of the temporomandibular joint in adult life. The following cases all showed some form of deviation of the mandible:—

Fig. 2.—Upper anterior crowding with left-sided cross-bite and instanding $\underline{2|}$. Before and after treatment.

Fig. 3.—Lateral deviation of the mandible. Before and after treatment.

CASE REPORTS

Case 1, *aged* $11\frac{1}{2}$ *years* (*Fig.* 1).—This was a Class I type, with two peg-shaped upper laterals in linguo-occlusion and a slight cross-bite. The upper and lower centres were not coincident. The treatment consisted of an upper plate with a Glenross spring-tension screw thickened behind the upper incisors. The screw was fully opened in 6 weeks, and was followed by pegging forward of $\underline{2|2}$. After being worn for 3 months the plate was removed and the bite allowed to integrate. The upper and lower centres now coincide.

Case 2, *aged* $11\frac{1}{2}$ *years* (*Fig.* 2).—Upper anterior crowding with left-sided cross-bite and $\underline{|2}$ instanding. There was insufficient space to allow $\underline{|2}$ into the arch. An expansion plate with a Glenross spring-tension screw was fitted and, by stages, the screw was opened to its full extent. This was followed by a second screw, and after this was fully expanded $\underline{|2}$ was brought forward by

Given at the Edinburgh meeting held on 11 May, 1962.

means of a rubber peg. The appliance was worn for a further 2 months and the bite then allowed to integrate. Total treatment time was 5 months, although the final casts were not taken till 1 year later.

Fig. 4.—Upper anterior crowding with left-sided cross-bite. Before treatment and relapse after first phase.

Fig. 6.—Cross-bite in deciduous dentition. Before and after treatment.

Case 3, *aged* 12 *years* (*Fig.* 3).—This was a Class I case with the loss of |6 and a cross-bite of the upper lateral segment from |2 backwards. The upper and lower centres did not coincide. The case was also of interest in showing two supernumeraries in the 7|7 region. The treatment was first by an upper plate covering the back teeth with a flat biting plane which allowed the mandible to assume its correct position. The upper and lower centres then coincided, and |2 was pegged forward. From this stage the patient was put on to an expansion plate with a Glenross spring-tension screw which was worn for 5 months. A good functional dentition was obtained, though perfection was lacking because of the loss of |6.

Case 4, *aged* 8 *years*.—The treatment in this case had to be effected in two phases. The first phase (*Fig.* 4) between the age of 8 and 10 years, the second (*Fig.* 5) at 13 years. The case showed an upper anterior crowding and a cross-bite in the right side. The treatment to begin with consisted of the extraction of DC|C and later the extraction of 4|4. An expansion plate was used at the age of 10 years, and the cross-bite eliminated. At this time, however, the bite was rising considerably and the appliance was taken out. As |3 started to erupt there was a relapse, and 2| was again inside the bite. The parent was extremely keen to continue treatment, but it was decided to wait until the permanent dentition had fully erupted before reconsidering treatment. Treatment was restarted at age 13 years, at which time 532| were in linguo-occlusion. An upper Schwartz plate was used with a lingual flange down the left molar region to give additional anchorage. This type of plate was worn for 6 months with a rubber peg in 2| and 3| for the last month. Thereafter, a Hawley retainer was worn and the final

Fig. 5.—Second phase. Before and after treatment.

casts were taken when the child was aged 15 years after the retainer had been out for 6 months. It has been stable since that time.

Case 5, *aged* 4 *years* (*Fig.* 6).—This patient was first brought for treatment because the parent noticed facial asymmetry at certain times. On examination, the mandible showed a deviation to the right and a right-sided cross-bite. After much consideration, and because the child was caries-free and was of high intelligence, it was decided to endeavour to correct the cross-bite at this time. An expansion plate with a small Glenross screw with fixation by means of two clips was inserted, the anterior clips being of the Shew-Anker type, the posterior being of a 0·8 mm. hard stainless-steel wire. The appliance was worn for 2½ months, and the cross-bite has been eliminated. The patient is now wearing a retainer until the bite is fully integrated.

CONCLUSION

I would say in conclusion that I have found this type of cross-bite to be more easily eliminated about the age of 11½ years when the premolars have erupted, rather than during the earlier period of mixed dentition, I have proved that the actual time of active treatment at this age is about 5 months, whereas in the case started in the period of mixed dentition duration was 5 years, from start to finish; with active treatment time being about 18 months. Thus the adage, 'To choose time is to save time', obviously applies not only to the patient but also to the operator.

REFERENCE

Korkhaus, G. (1926), quoted by Kantorowicz, *Int. orthodont. Congr.*, 45.

DISCUSSION

The President said that the meeting had listened to a very interesting paper by a general practitioner. Specialists were apt to get a little above themselves and forget that the majority of people who practised orthodontics were general practitioners. Miss Miller had shown some very interesting cases. She had shown that apparently

the expansion plate was not entirely outmoded, which was an impression one was apt to get. She had also put out for discussion the age of treatment.

Dr. J. R. E. Mills raised two points. First, did Miss Miller find it necessary to 'gag the bite' when using this type of expansion plate? Secondly, he personally felt that those cases where the mandible displaced into a bite of comfort on closing should be treated as early as possible. Did Miss Miller agree?

Mr. E. J. R. Bird asked whether, on the expansion plate, Miss Miller used the long lingual flange. She had mentioned one case where a Schwartz plate was used. He often found in such cases that unless a lingual flange was used, one tended to expand the other side more than one wished.

Mr. A. J. Walpole Day said that Miss Miller had mentioned that about 50 per cent of cross-bite cases cured themselves. Had she any record of how many cases of posterior cross-bite involved the permanent teeth, or was it mainly deciduous teeth?

Had Miss Miller any observation on the long-term effect on the lower arch? If the upper arch was expanded, did one get compensating contraction of the lower arch so that the total volume of the mouth was more or less the same at the end as when one started?

Had she any observation on the cases where one expanded the deciduous teeth? Was the expansion maintained when the permanent teeth erupted?

Mr. J. S. Rose asked about the number of turns per week made with the screw. In one case, two screws had been fully opened in 5 months. He had always been worried about turning the Glenross screw that fast.

Mr. S. Haynes asked if Miss Miller had treated cross-bite simply by extraction, without the use of the expansion plate.

Miss Miller, in reply, said that she sometimes used the raised bite and sometimes did not. She used a raised bite where she wanted to peg forward perhaps one of the anterior teeth. In other cases, she found that she could do without it, but one had to judge for oneself.

With regard to time and cross-bite in adults, she agreed that if it was not done at the right moment it might be more difficult.

If she wanted additional anchorage, the lingual flanges were quite satisfactory, but it was difficult to judge; sometimes one got them to work very well and sometimes they were not quite so easy. She used the spring-tension screw practically all the time; in the last case only, where there was temporary dentition, she had not used it. Far more turns could be put on a spring-tension screw and the child could be sent away for a fortnight. The reason she had not used it in the temporary dentition was that it was rather bulky.

With regard to compensatory contraction of the lower arch, she had not thought much about it as long as the bite integrated nicely. She did not really know what happened if one expanded in the deciduous dentition. On the whole, she thought that if it was really stabilized there should not be any trouble with the permanent dentition.

With regard to extraction of teeth and cross-bite, when one or two teeth were involved in a cross-bite, it was possibly the easiest thing to do. Again, one had to judge for oneself.

SOME DIFFICULTIES EXPERIENCED IN THE ORTHODONTIC TREATMENT OF PATIENTS WITH CLEFT LIP AND PALATE

By DORIS R. RIDLEY, F.D.S. R.C.S., D.ORTH. R.C.S.
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This paper is concerned with orthodontic treatment of patients, with repaired clefts of lip and palate, in the mixed dentition or permanent dentition. It does not, however, include presurgical dental orthopaedics, nor early orthodontic treatment in the deciduous dentition.

The presurgical alinement of arches in infants may well prove to be effective in reducing the severity of malocclusion of the permanent teeth. However, it is too early to judge the long-term effects, and in the meantime many malocclusions are developing without the benefit of this procedure and needing orthodontic treatment of the permanent teeth.

Retention of the maxillary arch, with cap-splints on deciduous teeth, to prevent narrowing of this arch after surgery on the palate, may have some lasting effect. Again, this is in the experimental stage at present.

Both these methods of early arch control are being tried at several centres now, and it will be interesting to compare the results when the patients concerned achieve adult dentition.

Early orthodontic treatment in the deciduous dentition appears to have rather disappointing results. Correct alinement of deciduous teeth does not necessarily ensure that the permanent teeth will follow into their predecessors' positions. Many children have been treated from very early years and yet seem to need as much orthodontic treatment at the permanent stage as do children left untreated. Thus early treatment appears to have little advantage; and would have the disadvantage of rendering child and parents disappointed with treatment and less enthusiastic and co-operative than those left untreated until the later stage.

Orthodontic treatment in the mixed or permanent dentition for these cleft cases is, of course, very similar to orthodontic treatment for non-cleft cases. However, there are certain differences peculiar to these cases, and it is some of these which will be discussed in this paper.

GENERAL MANAGEMENT OF CASE, AGE FOR TREATMENT, AND DURATION

Apart from early arch alinement and arch control, it would thus seem advisable to delay active orthodontic treatment until the permanent teeth begin to erupt. However, it is advisable to keep the child under observation during the early years, and a once-yearly visit should not be too much of a hardship for the parents. This has the advantage of the orthodontist becoming well acquainted with the child and parents, and making the parents feel that an interest is being taken in the child although no active treatment is being done. Most important of all, it enables the orthodontist to encourage good oral hygiene and regular attendances for conservation of teeth, which are so essential for these patients. Habits of regular visits to the dentist and good oral hygiene, if started at an early age, will stay with the patient for life. It is unfortunate that, in the past, these patients who have such problems with full dentures are the very ones with a careless attitude towards oral hygiene and dental treatment. Frequently, also, they have mouths which are not self-cleansing, with many areas of stagnation, and thus have poor gingival conditions and high caries rates.

Complete assessment of the case should be made and full treatment planned when the first permanent molars and permanent incisors have erupted. If any active treatment is needed for labial movement of lingually inclined maxillary incisors, this should be done at this stage, and as quickly as possible. Otherwise, the case should be left until the premolars and canines have erupted, and the active treatment carried out then.

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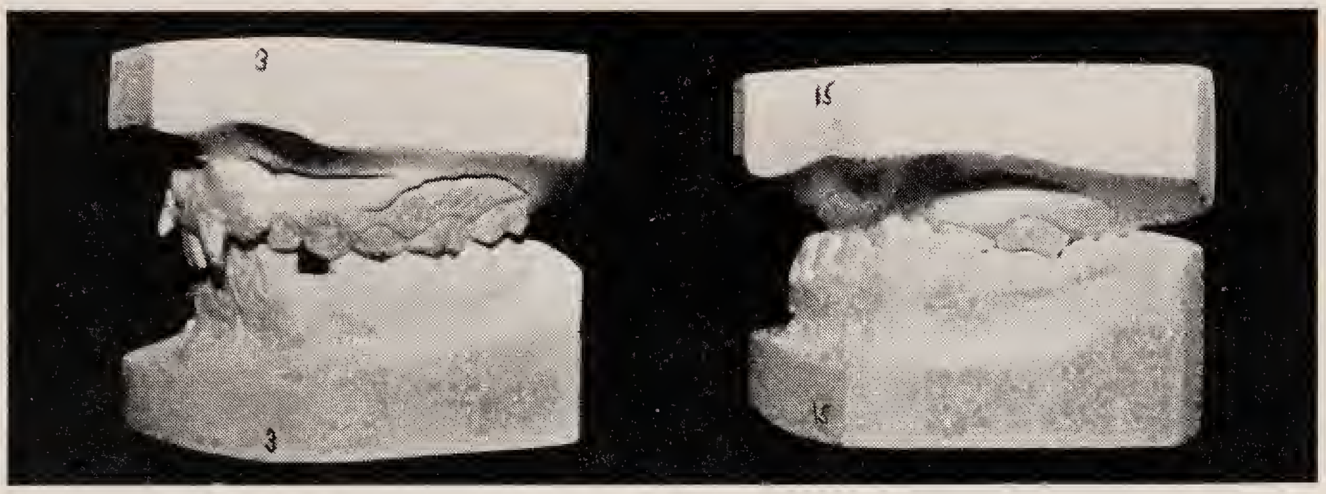
If this is done, the patient may well have only 12–18 months of active treatment altogether, and co-operation will be much better than when treatment is spread over several years.

It must be remembered that these patients often have speech defects, upper respiratory infections, or degrees of deafness, and they may be associated with malocclusions of different types, but the malocclusions may not be due entirely to the clefts. Indeed, in some cases it is possible for the cleft to be a not altogether adverse factor! For example, if the patient had a severe Skeletal Class II relationship, a cleft together with the following surgery could reduce the size of the maxillary arch and



A B

Fig. 1.—Cleft cases with (A) postnormal and (B) prenormal skeletal bases.

also need further plastic surgery. Thus they will be attending speech therapists, their own doctors, ear, nose, and throat surgeons, plastic surgeons, and even psychiatrists as well as their own dentists and the orthodontist. Therefore, orthodontic treatment carried out with a minimum number of visits is greatly appreciated.

ASSESSMENT OF CASES

In assessment of patients with repaired clefts of lip and palate presenting for orthodontic treatment, it should be remembered that these clefts occur in individuals of all types and of different genetic background. Thus the patient may have a perfectly normal occlusion, with a normal skeletal relationship and normal musculature, had the cleft not occurred. On the other hand, the cleft may have occurred in a mouth where the occlusion would otherwise have been of a Class II, division 1 or division 2, or Class III type, or a Class I type with overcrowding. Similarly, it may occur where the skeletal relationship might otherwise have been postnormal (*Fig.* 1 A) or prenormal (*Fig.* 1 B) and it may arise in a mouth with any combination of normal or abnormal musculature. Therefore, the clefts may well thus reduce the resulting malocclusion rather than increase it! On the other hand, a cleft associated with a basic Skeletal III relationship is going to render the final malocclusion much more severe.

Therefore, the basic genetic pattern of skeletal relationship, occlusion, and musculature should be determined. This is extremely difficult at times, especially in severe cleft cases. It is often helpful to be able to examine the parents, brothers, and sisters, and other relations if possible.

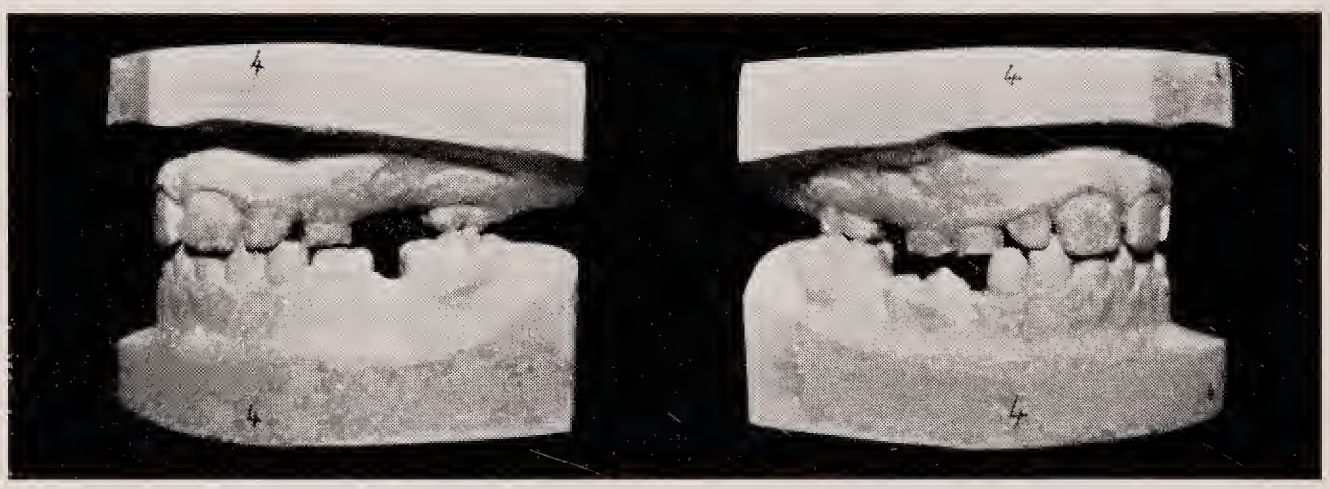
Sometimes there is a marked similarity between the patient and parent or other relative, the only difference being the cleft in the patient. This is very helpful in determining the condition of the patient had the cleft not occurred.

Then the disturbances actually associated with the cleft itself may be determined. These are due to:—

1. A basic shortage of tissues: (*a*) Bone; (*b*) Soft tissue; (*c*) Tooth germs.
2. An early disturbance of growth centres.
3. Surgery: (*a*) Joining together the edges of the clefts and affecting bone, soft tissues, and tooth germs; (*b*) Disturbances to growth centres.

Fig. 2.—Malocclusion associated with incomplete cleft of lip on left side.

A B C



D E

Fig. 3.—Reverse overjet in a case with cleft of soft palate (A, B, C) before and (D, E) after treatment.

Fig. 4.—Overcrowding where there was also a cleft of soft palate.

4. Withholding of growth by scar tissue.

5. Adaptation of muscles and growth to counterbalance the effects of the above.

6. The type of cleft, whether of lip or palate or both, whether unilateral or bilateral, complete or partial, and the severity, will obviously affect the situation.

TYPE OF CLEFTS AND EFFECTS ON OCCLUSION

Incomplete Clefts of Lip.—Incomplete clefts of lip, not involving the alveolus, will often have no effect on the occlusion, and often any malocclusion associated with these may be safely assumed to be due to other causes and the case may be treated as a non-cleft case. If there is an associated malocclusion, it is local to the cleft region and is usually a supernumerary or an absent lateral incisor. The case shown in *Fig.* 2 had an incomplete cleft lip, but no cleft of alveolus. There is no visible effect on the arch, but a supernumerary is present on the affected side.

Incomplete Clefts of Soft Palate.—Similarly, incomplete clefts merely of the soft palate tend to have a minimal effect on the occlusion, and malocclusions occurring with these clefts may often be treated as non-cleft cases, as they are due to factors other than the cleft itself.

The models shown in *Figs.* 3 and 4 are of patients with clefts of soft palate only. *Fig.* 3 A, B, C shows a case of cleft of soft palate with a reverse overjet. It was debatable whether or not this was due to the cleft. There was a strong family history of Skeletal III with reverse overjet, which made us wonder whether this was not due to the cleft, but would have occurred anyway. *Fig.* 3 D, E shows the case after correction of the reverse overjet. *Fig.* 4 shows models of a case which has a cleft of the soft palate and will also be very overcrowded. However, the lower arch was grossly overcrowded also, which would point to the fact that the crowding of the maxillary arch is due, not to a narrow arch caused by the cleft and surgery, but to a tooth/tissue disproportion generalized in the mouth. Had the case had a more severe cleft it would have been easy to confuse the issue and judge the overcrowding to be due to disturbances related to the cleft. A more severe cleft would have made matters worse,

A B C

D E

Fig. 5.—Local disturbances on cleft line.

but would not have been the prime cause of the crowding.

Severe Clefts of Palate.—The more severe clefts of palate alone may cause a narrowing of the upper arch and this may present as a tendency to cross-bite. Often even these do not cause a great deformity, and associated malocclusions, such as severe overcrowding, may well have been present apart from the cleft.

Clefts of Alveolus.—The situation becomes more definite where the alveolus is involved, either with cleft lip only or with cleft lip and palate. With cleft lip only and cleft alveolus there are local disturbances of the cleft line. The palate also being involved leads to malalinement of arches as well.

The Local Disturbances in the Cleft Line in the Alveolus are:—

1. Absent teeth—usually lateral incisors (*Fig.* 5 A).
2. Supernumerary teeth—maybe several (*Fig.* 5 B).
3. Malformed teeth: (*a*) Dilaceration; (*b*) Hypoplastic crowns (*Fig.* 5 C).
4. Rotation of teeth at the edge of the cleft, i.e., central incisors and canines (*Fig.* 5 D).
5. Lack of full eruption of teeth adjacent to cleft line (*Fig.* 5 E). (Sometimes this extends to the opposite central incisor and the first premolar.)
6. Lack of bone in cleft line preventing movement of teeth.

Other dental disturbances, such as an absent second premolar on the opposite side or signs of overcrowding, are not likely to be due to the cleft but would probably have been present anyway.

The Result of Malalinement of Arches will be:—

1. Palatal collapse of the maxillary lesser buccal segment with the posterior part of this buccal segment often in good occlusion with the mandibular arch, but the anterior part completely lingual (*Fig.* 6).

Fig. 6.—Collapse of maxillary lesser buccal segment.

2. Lack of full eruption of teeth at the part of the segment nearest the cleft.
3. Either: (*a*) A rotation outwards and forwards of the incisal part of the greater segment; or (*b*) A flattening of the labial segment with lingual occlusion of the maxillary incisors.

Fig. 7.—Bilateral collapse of maxillary buccal segments.

Bilateral Clefts of Lip and Palate.—In cases of bilateral cleft lip and palate, often there is a bilateral collapse of the maxillary buccal segments with the labial segment left forward (*Fig.* 7). Local abnormalities occur in the alveolar clefts, but, added to this, there may be a mobile premaxilla. Some of these results depend on the type of surgery employed.

These are the main effects of clefts on occlusion, and any other deformities may well not be due to the cleft at all.

Growth and Development.—However, there will also be effects of interference with growth centres and these may show as a tendency to a developing prenormality, and, possibly, as developing anterior open bite.

Also, there may be effects of the adaptation of muscles and effects of surgery on muscles. It may be that the tightness sometimes produced in the upper lip with cleft of lips may cause flattening and retroclination of upper incisors. The lower lip may not control as much as otherwise and the adaptation of lip and tongue to difficult speech mechanisms may have some effect. This is not yet fully understood. It must be remembered, also, that all varieties of abnormal muscle action are as likely to occur in these cases as in non-cleft cases. Some affect the condition adversely; some may help, e.g., an anterior tongue thrust retaining an edge-to-edge incisor bite which would otherwise collapse lingually.

Some research work to try to relate these factors of basic genetic patterns, and the effect of clefts and surgery, to malocclusion is at present being carried out at Great Ormond Street, and it would be better to leave further discussion of these points until that work is published.

However, it is seen that many different factors are involved, and these should all be fully assessed by clinical observation of patient and family, radiographs, cephalometric radiographs, and models, before a complete diagnosis is made and a plan of treatment formed.

Thus, if the cause of the malocclusion can be determined, whether actually due to the cleft or not, it will help to determine the prognosis.

If the malocclusion present is due to factors other than the cleft, then the treatment and prognosis will be the same as in a non-cleft case. It is in the treatment of the malocclusion believed to be essentially due to the cleft that some peculiar problems arise, and these problems are likely to be related to the aetiology.

CLINICAL PROBLEMS

Aetiological Classification.—There are three main aetiological headings under which orthodontic treatment of abnormalities due to clefts may be discussed: (1) Local abnormalities in the cleft line in the alveolus; (2) Arch malalinement; (3) Growth disturbances and adaptations.

These three are, of course, interrelated and usually all three are present to some extent. The division is mainly for descriptive purposes.

1. Local Abnormalities in the Cleft Line in the Alveolus.—During treatment, the factors to consider in these cases are:—

a. Shortage of all tissue, reducing the area in size.

b. Lack of bone.

c. Absent tooth germs.

d. Damage to tooth germs.

e. Presence and effect of scar tissue.

The Clinical Problems are:—

i. *Absent teeth*: This is one of the commonest deformities in a cleft alveolus case, and the tooth usually absent is the lateral incisor, although the central incisor and the canine may also be missing. It is difficult to determine whether the tooth germ was congenitally absent or whether it was destroyed during surgery. It may have been damaged to produce an aberrated form.

The treatment of these absent teeth depends tremendously on the rest of the occlusion, and on the width of the cleft. If there is any overcrowding present it may be possible to close the gap by moving the teeth round and closing the canine up to the central. This can be achieved quite satisfactorily in non-cleft cases where teeth are absent. However, this is where the limitations imposed by the cleft become apparent. Sometimes the rest of the arch may be so overcrowded that one or two teeth need to be extracted, and yet this gap cannot be closed. This is due to lack of bone in the cleft and also to the presence of scar tissue. The edges of the alveolar bone on either side may well have compact bone over them, and thus the adjacent teeth cannot be moved into the gap.

Sometimes, where there is a very small deformity of bone, it is possible to achieve an

acceptable result by moving the canine and central as far as possible and then accepting a small space. Quite often, indeed, the teeth erupt into such positions. There is a section of alveolus missing, and if the teeth erupt into their otherwise usual positions they will be closer together than normal.

Occasionally the central and canine may be forced closer together by tipping the crowns, although the roots stay out of the cleft. These are unstable, however, and will need permanent retention by interlocking inlays. Such retention may be satisfactory for several years, but if the teeth are under a considerable strain the supporting tissues are likely to break down, with early loosening of the teeth.

Where there is a wide gap the only solution is a bridge or denture, and the choice should be made as follows:—

A bridge is indicated where there is no other gap in the dentition and no permanent retention is needed elsewhere; where no obturator is required, and where the teeth on either side of the cleft are in good condition functionally and aesthetically, and suitable abutment teeth are available. If the adjacent teeth need permanent retention after movement, e.g., correction of rotations, then a bridge can do this as well. A bridge is, of course, much easier for the patient and is probably the best choice.

A denture is indicated where an obturator is needed as well or where permanent retention of the arches is required. Of course a denture is also indicated where other teeth need replacement or where there are no teeth suitable for abutments. As cleft-palate mouths tend to be far from self-cleansing, and there may be a higher caries rate, a skeleton metal denture is probably the best choice, if possible.

If the adjacent teeth are of poor quality it is better to replace these as well as the lateral incisor.

If there is a small gap it may be possible to make use of a supernumerary in the area and crown it as a lateral incisor. However, in view of the limitations of the cleft site these can very rarely be brought into position any more than can the central or canine.

Some research is proceeding at present with bone-chips inserted into the cleft line. This may enable teeth to be moved into the cleft line or it may be possible to transplant teeth into the cleft line. Such surgical aid would, of course, be extremely beneficial. In view of the presence of compact bone at the edges of the cleft and the impossibility of moving teeth through this compact bone, it would be advisable for the surgeon to remove this and freshen the edges before inserting bone-chips.

ii. *Supernumerary teeth*: These are often present in the cleft line. They may be present whether the lateral incisor is present or congenitally absent. They may take the form of supplemental lateral incisors or may be small, conically shaped teeth. They may be single or multiple, inverted, rotated, and in a variety of positions on either side of the cleft line. They may remain unerupted. They are probably caused by disturbance to the lateral incisor tooth germ.

Sometimes the supernumerary may be an aesthetically better tooth than the actual lateral incisor, or its root may be in a better position. Therefore, it is often advisable to wait until all the supernumeraries have erupted before extracting any teeth. The appearance may be rather peculiar, with several teeth erupting at odd angles, but it is often safer to do this than to make a hasty decision and extract the best tooth as a result.

The position of the root is possibly more important than the appearance of the crown. If the root is in a good position it may be crowned. If the crown is good but the tooth in a hopeless position, not much can be done, and it is better extracted.

Careful radiographs should be taken, and the case then kept under observation until the teeth erupt. If, of course, they are preventing eruption of the lateral or central incisor or canine, then surgical intervention is indicated. If it appears that they are not going to erupt, then it is usually wiser to remove these surgically unless it is judged that this will damage the adjacent teeth, or unless they are so tiny they are unlikely to cause trouble.

iii. *Malformed teeth, misplaced teeth, and rotations*: Often associated with clefts of

alveolus are rotated and misplaced central incisors, lateral incisors, canines, and even premolars. Also, severe tilting occurs, usually with the crown towards the cleft linc and the root away from the cleft line.

Similar rotations and irregularities in non-cleft cases may often be corrected quite easily, especially with the use of fixed appliances—twin wire arches, multiband round arch with auxiliary springs, or edgewise. However, in cleft cases, although sometimes a good result is possible, more often the teeth either refuse to move, become very loose, or promptly relapse, if any movement is achieved. This is mainly due to lack of bone in the cleft line as mentioned before, but is also caused by dilaceration of the roots of the teeth concerned. Often the roots are badly mis-shapen, although the crowns may appear to be normal.

To avoid disappointment, it is best to take several radiographs, from different angles, in order to diagnose the condition before attempting movement. In cases of badly dilacerated teeth it is better either to accept the position, possibly with crowning, or remove and replace.

The cause may well be surgical intervention and damage to tooth germs, or it may be the effect of lack of bone on the developing root.

iv. *Lack of full eruption of adjacent teeth*: This may also be due to dilaceration of the teeth concerned, but is more often caused by malalinement of arches or lack of downward growth of the alveolus and will be discussed later .

2. Arch Malalinement.—During treatment of arch malalinement it must be remembered that the factors responsible for the malocclusion are:—

a. Lack of tissue in the palate.

b. Lack of tissue in the alveolus in the cleft area.

c. Scar tissue.

These three combine to place the smaller posterior segment inwards towards the midline and upwards anteriorly.

The part of the labial segment adjoining the cleft will tend to be placed more palatally to make up the deformity, and the part adjoining the cleft is thus upwards and backwards. Alternatively, this part of the labial segment may be rotated forwards and a wide cleft result. In bilateral cases, the two posterior segments have a tendency to go in towards the midline and upwards anteriorly. The labial segment may be pushed palatally or may be left out labially. In bad cases, the premaxilla may be quite mobile and it is sometimes possible to move this labially by simple manipulation. It will move freely during mastication.

These arch malalinements are often associated with the third main factor, i.e., growth disturbance.

The Clinical Problems are:—

i. *Buccal segment malposition*: The deformities of the maxillary posterior segments will produce varying degrees of cross-bite, depending very much on the relative size of the mandibular arch. If there is a comparatively narrow mandibular arch there will be a good chance of an acceptable posterior occlusion. However, if the mandibular arch is normal or wide there will be either a cusp-to-cusp relationship or cross-bite, unilateral or bilateral, and varying in severity.

Often teeth are tilted palatally or the whole segment will be palatal with the teeth upright. The tooth movement to correct this is a lateral expansion of the arch in order to obtain a good buccal occlusion. In a non-cleft case of cross-bite, where the fault is dental and not skeletal, the lateral expansion, with bite-blocks to free the bite, is a fairly simple procedure, and, if cuspal locking is achieved, there is a good chance that the occlusion will remain stable.

However, in cleft cases there are two main differences:—

α. More expansion is needed anteriorly and quite often the molars do not need any at all. If straightforward expansion is used, the molars will end up in buccal occlusion.

β. Shortage of tissue.

To overcome the first difficulty it is best to use a double expansion screw so that the anterior part of the arch is expanded more than the posterior. Alternatively, a coffin-type palatal spring can be used instead of a screw. A coffin spring attached to cap-splints may be used sometimes.

An even more effective method is a palatal arch, fixed to bands on the molars, with auxiliary springs acting on the teeth in lingual occlusion—usually the canine and premolars. However, if a fixed appliance is used, often a removable appliance, either upper or lower, with bite-blocks, is needed to clear the bite. The palatal arch with auxiliary spring is more effective than multiband for this type of movement. The second difficulty may show itself after the expansion is achieved, when it may be noted that the teeth have been swung upwards as well as outwards. This is due to lack of supporting tissue.

If the teeth are retained in the required buccal position, it will be seen that they do not overerupt into position, as might be hoped. They merely stay out of occlusion. Thus the result is unstable and functionless. The only solution is permanent retention with an overlay denture or onlays.

Fig. 8 A–C shows models of a patient before treatment. The posterior occlusion is good in the molar regions, but shows a bilateral cross-bite in the premolar regions as well as reverse incisal overjet. $\frac{6\ \ |1\ \ 6}{|\ \ 5}$ had to be removed due to caries and $\underline{|5}$ due to the extreme palatal position; then appliances were used to attempt correction of the reverse incisal overjet and to improve the buccal occlusion by lateral expansion.

A B C

D E F

Fig. 8.—Models (A, B, C) before and (D, E, F) after treatment, showing lack of occlusion following expansion.

Fig. 8 D–F shows the case nearing the end of treatment. It will be seen that, although the occlusion is reasonable on the right side, on the left side (i.e., the side of the lesser segment) the teeth have been swung up out of occlusion as they were moved laterally. The result is unstable and non-functional. As the patient has to have a denture to replace teeth, he will be fitted with a skeleton metal denture which will retain the teeth, and with an overlay for functional purposes.

The long-term result of permanent retention of these unstable occlusions is unknown, but if the denture is properly constructed and well

looked after it should not cause too much trouble.

Another result of maxillary arch expansion may be to open up a fault in the palatal closure which had not been apparent previously, as the edges of the fault had been closely applied. Further surgery may then be required, or an obturator needed. It is interesting that an actual breakdown of repaired tissue has never been noted as a result of orthodontic treatment. Also, buccal expansion may result in labial collapse. All these are due to a fundamental shortage of tissue.

Surgical correction of maxillary buccal segments with bone-grafts is being tried in several centres now and may prove to be more successful than orthodontic treatment for the worse cases.

ii. *Lack of eruption of canines and central incisors*: Teeth on either side of the cleft of alveolus are often tilted and not fully erupted. This may be due to the tooth form as discussed above, but it is often due to the edges of the segments being placed upwards and inwards, and to shortage of tissue.

Unerupted teeth in non-cleft cases may often be uncovered and brought down into satisfactory alinement. However, in cleft cases there is not the supporting alveolar bone available and the alveolus is directed upwards to the cleft. Thus the tooth may be treated in the same way as in a non-cleft ease, e.g., with round-arch multiband and auxiliary springs—but the tooth will often not move at all, or loosen, or, if brought down, will rapidly ascend again.

It must be realized that the alveolar arch to support the tooth is just not sufficient and is in the wrong place itself. The only treatment is crowning or replacement if the original position is not acceptable.

Similarly, the canine is often palatal in position and the lateral movement of this tooth is limited in the same way and for the same reasons. It is the alveolar bone itself which is misplaced and not the tooth.

iii. *Mobile premaxillae*: The problem of mobile premaxillae is more surgical than orthodontic. Any appliance therapy to correct the teeth in a mobile segment will be of doubtful lasting value. It seems that the whole mobile premaxilla moves and not the individual teeth.

These malocclusions due to malalined segments are the ones likely to be prevented or minimized by preoperational orthopaedics, but there will be the problem of tissue shortage. If the arches are kept in good alinement, it is likely that the area of the cleft will be wider still.

All these malocclusions tend to become worse with growth and development, and thus are related to the third group of aetiological factors.

3. Growth Disturbances and Adaptations.—These are due to:—

a. Disturbances of the usual downward movement of the maxillary complex.

b. Disturbance of the usual forward movement of the maxillary complex.

c. Adaptation of soft tissue to overcome shortage of tissue.

The Clinical Problems are:—

i. *Relapse of labial movement of maxillary incisors*: Labial movement of maxillary incisors is one of the simplest and quickest forms of orthodontic treatment in non-cleft cases. Provided that the case is not limited by adverse skeletal relationship and there is sufficient room for the teeth, maxillary incisors can often be moved labially over the lower incisors in a few weeks. Once in correct position with a normal incisor overbite, the teeth are usually stable and need very little retention.

In cleft cases, where the maxillary incisors are in lingual occlusion and with normal to excessive incisor bite at around 7–8 years of age, the teeth may be moved as easily as in any other case. However, it is not unusual for them to relapse completely, even if they have quite a considerable overbite. This relapse is not instantaneous. The incisors will appear to be behaving as in a non-cleft case at first and for several months will be quite satisfactory. However, it is not unusual for gradual relapse to occur over several months, usually with reduction in overbite. Once relapsed, it is often difficult, or impossible, to replace these in a labial position.

Fig. 9 A shows models of a patient with a reverse overjet. In *Fig.* 9 B it will be seen that |1 has been moved labially and has quite a reasonable overbite. *Fig.* 9 C shows the same case with a relapse of the overjet. It will also be seen that there is a change from deep overbite in the first set of models to an open-bite tendency.

Associated with this relapse is an increase in Skeletal III tendency, also in anterior open-bite tendency. Sometimes an excessive incisor overbite will become an anterior open bite. In some ways it is similar to the kind of increase in deformity seen in non-cleft Class III cases around puberty, only in these cleft cases it occurs at an earlier age. It would seem to be an inhibition of the maxillary growth complex, rather than an overdevelopment of the mandible as is believed to occur in the non-cleft cases mentioned above.

An inhibition of the downward and forward growth of the maxillary complex, while the mandible proceeds normally, would have this effect of decreasing the overbite and producing a reverse overjet, especially in cases with a Skeletal III tendency in the first place.

Other factors concerned, which may assist in this relapse, may be:—

α. The presence of tight scar tissue in the upper lip causing pressure on the incisors. Also, there may be

β. An increased interocclusion clearance, associated with lack of basal and alveolar bone growth in the maxilla, or it may be an habitual open-mouth posture associated with upper respiratory affections which so frequently occur in these cases. This open position will permit relapse of incisors which might otherwise be held by the bite.

γ. An associated low tongue position which supports the lower incisors but not the upper incisors.

δ. Dilacerated teeth, as mentioned previously.

This type of relapse is difficult to prediet. It is best to have a longer period of retention to attempt to keep the maxillary incisors in a labial position and encourage retroclination of the lower incisors. However, if this condition deteriorates, surgical correction may be the only answer.

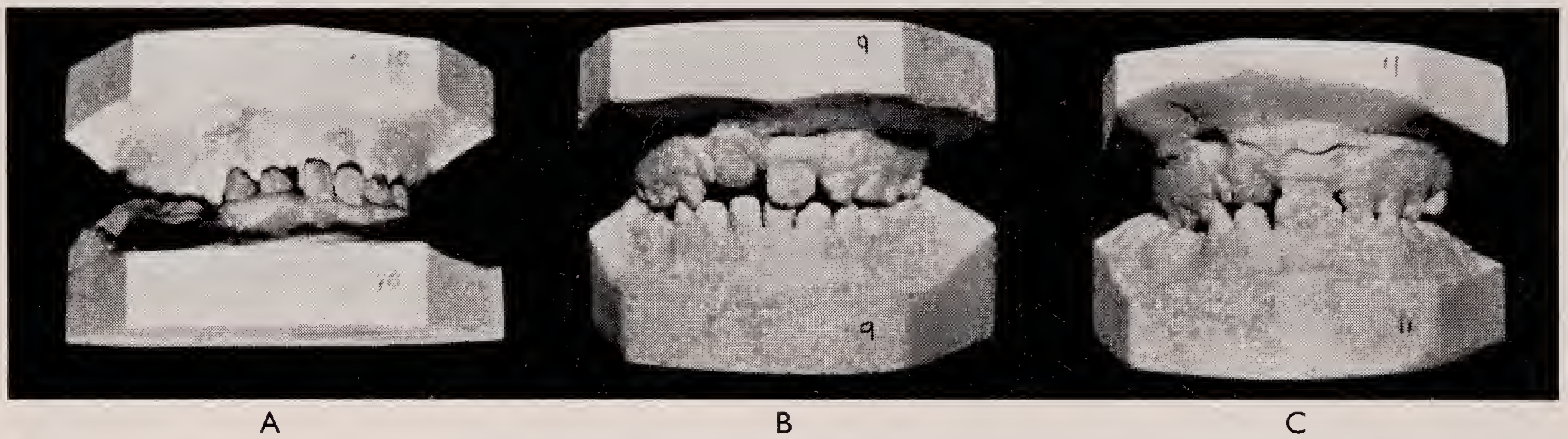


Fig. 9.—Relapse after labial movement of incisors.

ii. *Lack of occlusion of buccal segments*: Lack of downward growth of the maxillary complex may partly explain the lack of occlusion of buccal segments of cleft cases after these segments have been moved laterally. As has been previously mentioned, this may also be due to lack of tissue to support the teeth.

iii. *Lack of complete eruption of teeth*: As well as the factors mentioned above for the apparent lack of full eruption of teeth in cleft cases, the lack of full downwards and forwards growth may also be a contributory factor.

These conditions of relapse and non-eruption in relation to growth disturbances are difficult to prove conclusively, but the longitudinal study of cleft cases will throw more light on these observations. Inhibition of growth is obviously untreatable orthodontically and only surgery or prosthesis can correct defects produced in this way.

CONCLUSION

The success of orthodontic treatment of patients with treated cleft of lip and palate therefore appears to lie chiefly with the original assessment and diagnosis. Most cases have many varying factors contributory to the malocclusion, some of which, but not all, are associated with the cleft. In dealing with problems directly associated with the clefts the main points to remember are shortage or absence of tissue and the effects of interference with growth and development of all the individual tissues. The limits of the case should be realized, and orthodontic treatment should be assisted by surgery and prosthesis when these limits are reached. Often a combination of all three will give excellent results.

Acknowledgements.—I should like to express my gratitude to Miss R. Caseley, Mr. T. Cradock-Henry and Professor D. P. Walther for all their help and for permission to publish this paper. I should like to thank the other members of the staff of the Dental Department at the Hospital for Sick Children, Great Ormond Street, for their help, and also Mr. C. Hunt of the Photographic Department, Raigmore Hospital, Inverness, for photographs and slides.

DISCUSSION

Professor D. P. Walther, opening the discussion, said that we had formed the impression that there was an association between a family history of Skeletal Class III and Veau III or IV. He asked Miss Ridley whether that was borne out in her present ethnic group.

He noticed that she just skated over the presurgical dental orthopaedic treatment and said that she was awaiting the long-term result of it with great interest. He felt that that was a very commendable attitude.

Miss Ridley had said that she was very disappointed in early orthodontic treatment in the deciduous dentition. He whole-heartedly agreed with her.

He asked her whether she had seen many submucous clefts. He remembered one which had impressed him very much. The occlusion was almost normal, just tending towards a Class III, and the child showed the typical lack of development of the middle third of the face. The soft-tissue morphology appeared normal, including a perfectly adequate and mobile soft palate, and yet the speech tended to be of the cleft-palate type.

He agreed with her that the problem of moving teeth into the cleft space was a very difficult one. He was most interested in the research that was being done by Professor B. Johanson in Göteborg. If it was a fact that teeth could erupt into, and be moved into, the bone-graft area, then treatment would be revolutionized.

He was sure Miss Ridley would agree that, where one or both buccal segments had been swung out during treatment and the result retained with a denture, it was most important that the patient should always carry a spare denture. It was amazing how very quickly the buccal expansion collapsed if not retained.

Finally, he asked for her views concerning the treatment of the small postoperative perforations so often seen. Did she advise surgery, covering with a plate or obturator, or attempting to close it by stimulation?

Mr. S. G. McCallin wondered whether members of the Society in general practice, or Miss Ridley herself, could produce records of older patients who had worn retainers for many years, in order to assess the long-term results of retention.

Mr. D. A. Dixon agreed whole-heartedly with Miss Ridley's view that the treatment must be completed in the shortest possible period. One must plan treatment in such a way that one knows where one is going from the retention viewpoint, and not treat in the deciduous dentition, unless there are very strong indications.

Professor Walther had mentioned preoperative alinement. In Edinburgh, they had been doing that for five years and had got some children through to the full deciduous dentition and, comparing them with children who had not had that treatment, one saw that the degree of lateral collapse was reduced, from over half of the cases to under one quarter, but still some collapsed laterally. There was a small degree of anterior collapse in both groups with and without the treatment.

In an analysis he had done on the parents of children with cleft palates, one of the points examined was the dental base relationship. With the alveolar cleft in the children, there was a strong Skeletal III tendency in the children and, to a slightly lesser degree in the parents. With a postalveolar cleft, there was a Skeletal II tendency in the children, but, rather remarkably, not in the parents—again a slight tendency to Skeletal III. He felt that they blamed the surgeons a little too much these days and that the pendulum had swung too far. They now considered that any small arch was due to the surgeon. There was little experimental evidence for that, and some attention should be drawn to the familial tendency to Skeletal III and small upper jaws in these children.

A practical problem which defeated him utterly was the problem of vertical height discrepancy, especially in the alveolar cleft, when, for example, in a bilateral case, one could find a premaxilla some distance below the lateral segments. Could Miss Ridley help with that type of problem?

Mr. G. H. Roberts asked Miss Ridley if she made any observations on the incidence of cleft palate in relation to geographical isolation and possible intermarriage in closely knit communities?

Mr. D. G. Glass said that the paper was very interesting to him, especially as it came from a separate and different school from the one of which he was a member. He was sorry that the discussion had been opened by a member of that same school.

First of all, he would agree with Professor Walther and Miss Ridley that there was much to be said for bone-grafting into the area of the cleft. The trouble was to persuade a plastic surgeon to do it.

He noted that at Great Ormond Street they preferred to treat cases in the complete permanent dentition. He preferred to swing out the misplaced segments as soon as possible, to facilitate natural eruption and alinement of the teeth. Would Miss Ridley indicate her objections to that line of treatment?

He would like to know what Miss Ridley considered the right treatment for small residual fistulae in the anterior palate. He would also be interested to know what relationship she had with the plastic surgeon and at what age she saw the children with the plastic surgeon and what she told the surgeon he ought to do. Did she tell him what he ought not to do?

Miss Ridley said that Professor Walther had mentioned the association between the family history and the cleft types and asked whether she noticed it in the north of Scotland. From the work at Great Ormond Street there seemed to be a correlation, although the final statistics had not yet been worked out. With regard to the connexion with patients in the north, she had been there only a year and it was rather early to draw any conclusions.

She had not seen many submucous clefts. She was sure there were several about, but probably they did not present for treatment.

Small postoperative perforations were more a surgical problem. It was obviously better for the patient to have it closed surgically, if at all possible. Alternatively, if they had to wear a denture of some type, it was quite reasonable to use this to cover the hole. She had seen a few cases with the stimulation of the edges of the cleft. She was not very convinced that the holes could be closed completely.

With regard to long-term effects, dentists were very co-operative in the north of Scotland and she was sure they would show her all their cases. There was one drawback. Mr. McCallin could not have seen many adults in the north of Scotland, but they were nearly all edentulous!

She was interested to hear Mr. Dixon's observations on preoperative alinement that had been going on for five years. It certainly sounded encouraging. It would be interesting to see what happened when the permanent teeth erupted. The problem of vertical height was again the basic shortage of tissue and it was either a matter of surgery or prosthesis. There was nothing much one could do about it orthodontically.

In answer to Mr. Roberts, she said that she had not really seen enough clefts in the north of Scotland to be able to give any figure on the subject, and although there was certainly intermarriage in the Islands, it did not strike her that there was any greater incidence.

She informed Mr. Glass that she was not now at Great Ormond Street. If his results were better than hers, she could only say he must be getting less severe types of cleft!

When she was at Great Ormond Street, she had seen quite a few children who had had early treatment, and it was found that they still needed a lot of orthodontic treatment in the permanent stage. She would be interested to see if, in Mr. Glass's cases, when the permanent teeth erupted, they really erupted into the arch or whether it was found that they had to be treated again in that stage.

With regard to her relationship with the plastic surgeon, there were several plastic surgeons at Great Ormond Street. One or two of them were very interested in the orthodontist's work now. Certainly in the north of Scotland it was very good.

ERUPTION OF LOWER THIRD MOLARS FOLLOWING ORTHODONTIC TREATMENT

By D. G. HUGGINS, B.D.S., F.D.S., D.ORTH. R.C.S. (ENG.)
Senior Registrar, Liverpool Dental Hospital

LOWER third molar teeth have been referred to as the *bête noire* of the oral cavity. The patient is apprehensive of these teeth erupting and the operator may need special knowledge to deal with the problems which they create.

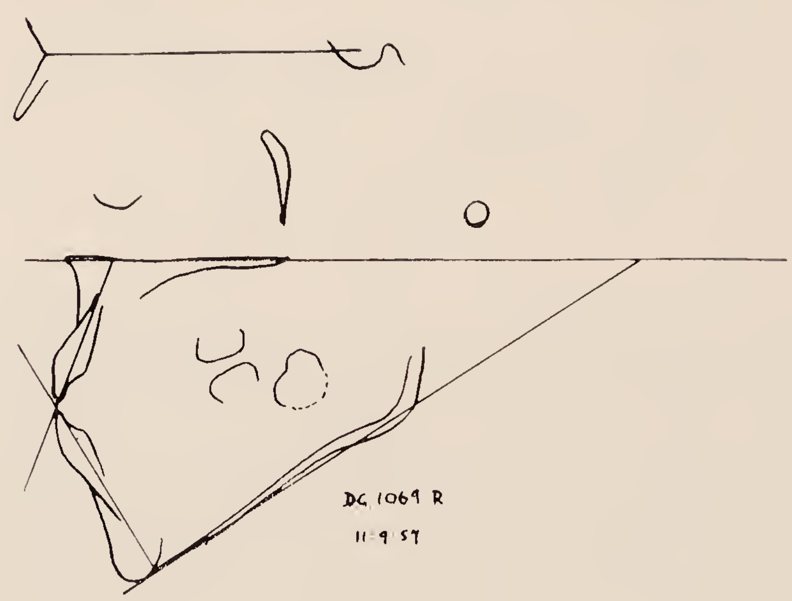
FREQUENCY OF IMPACTION

Third molar teeth are impacted in 9·5 per cent of male and 23·8 per cent of female patients, and of these more than half are in the lower jaw.

A

B

Fig. 1.—Patient D. G., 1957. A, Record models; B, Tracings of lateral oblique radiographs, to indicate $\overline{8|8}$ position; C, Tracing of lateral skull radiograph to illustrate relation of labial segments in the rest position.



C

AGE OF ERUPTION

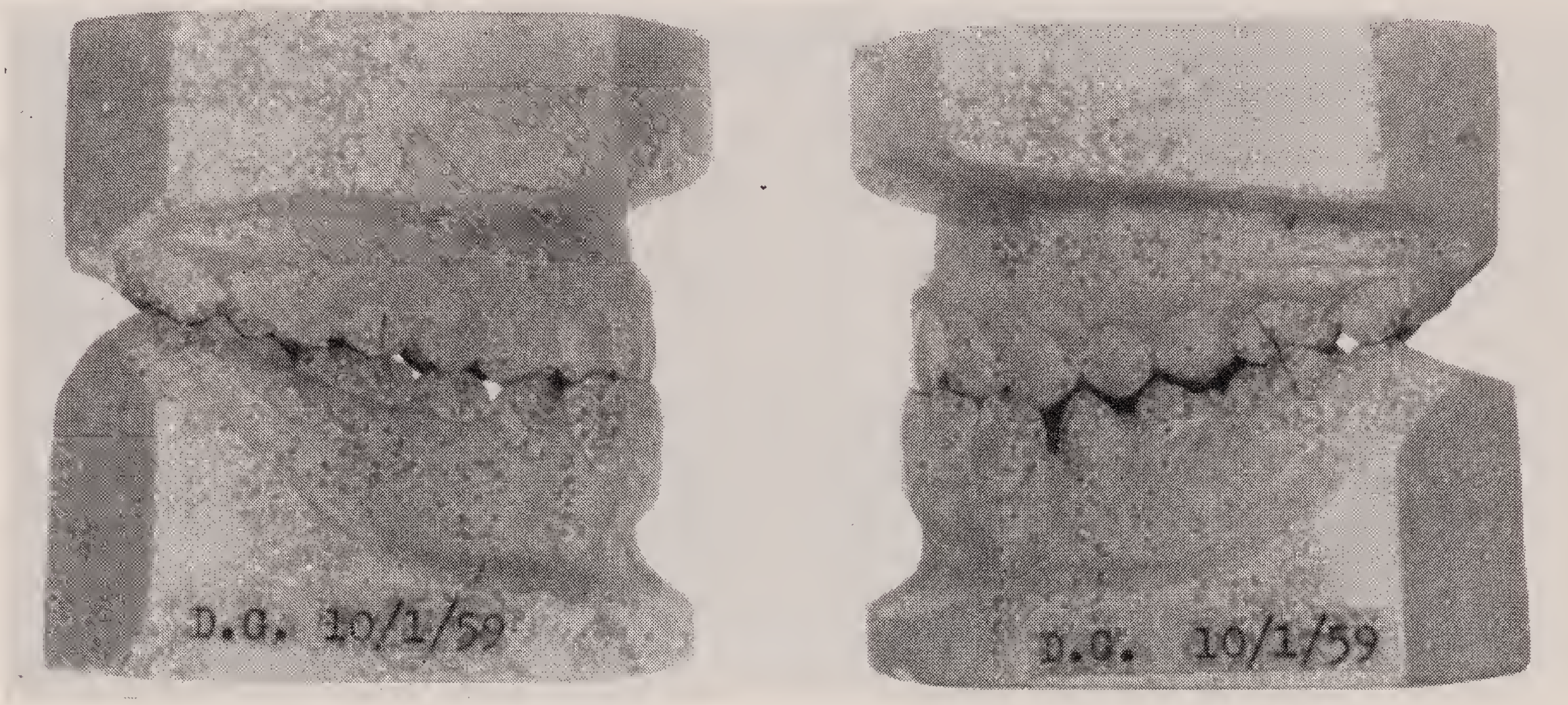
Clinical signs of the presence of lower third molar teeth may be observed at 16 years of age, the average age for eruption being 20 years 6 months in both male and female patients. In 12 per cent of Europeans third molars are absent (Hellman, 1936).

THE CAUSE OF IMPACTION

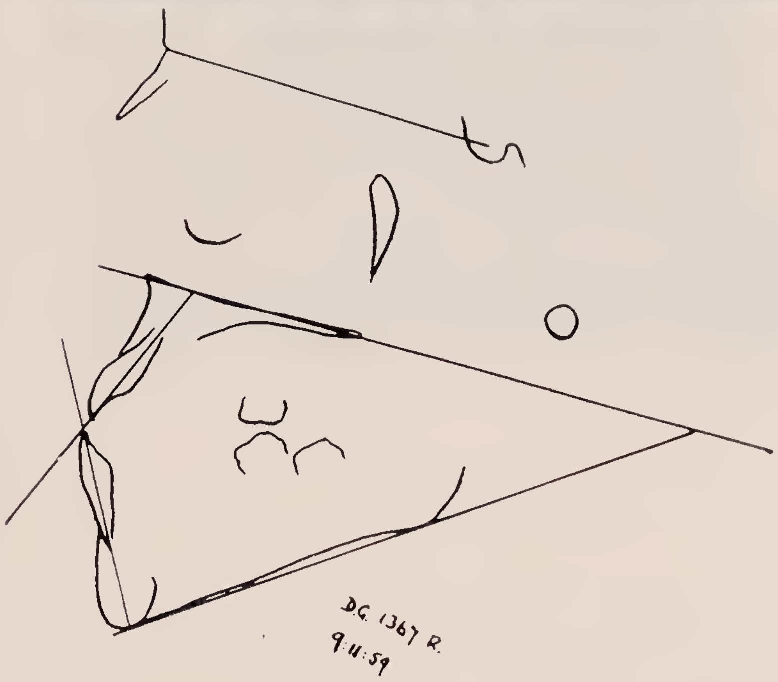
In present-day jaw development there is often an adverse tooth-to-bone-tissue ratio; following from this, teeth of the permanent series are likely to be excluded from the arch line. Third molar teeth vary in form and position. The lower third molar develops in the

Given at the Edinburgh meeting held on 11 May, 1962.

ramus of the mandible, and moulding of the anterior border of the ramus allows it to erupt into arch line. Lower third molars begin to calcify with the occlusal surfaces tilted mesially,



A



B

and as the alveolus increases in length the roots drift forward, correcting this tilt. The bulk of bone buccal to the lower third molar prevents deviation which would allow eruption to occur.

The frequent occurrence of impacted lower third molars can be accounted for as follows:—

1. Lower third molar teeth are the last teeth of the permanent series to develop.

2. The crypt position shows considerable variation.

3. Uprighting of the tooth during development is required to avoid impaction.

SEQUELAE OF ERUPTION

The eruption of lower third molar teeth may be accompanied by an inflammatory reaction of surrounding tissues leading to pain locally, and a disturbance of general health. Disturbance of alinement of other teeth present may also be observed.

Fig. 2.—Patient D. G., 1959. A, Record models; B, Tracing of lateral skull radiograph.

TREATMENT

My interest in this subject was first aroused by discussion among members at previous meetings of this Society. Subsequently, the matter was brought into focus when a patient

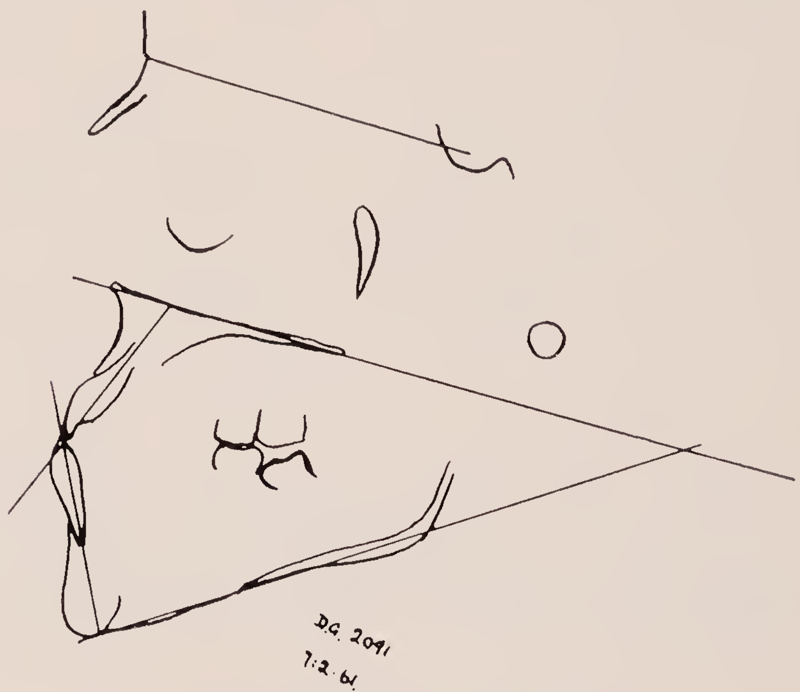
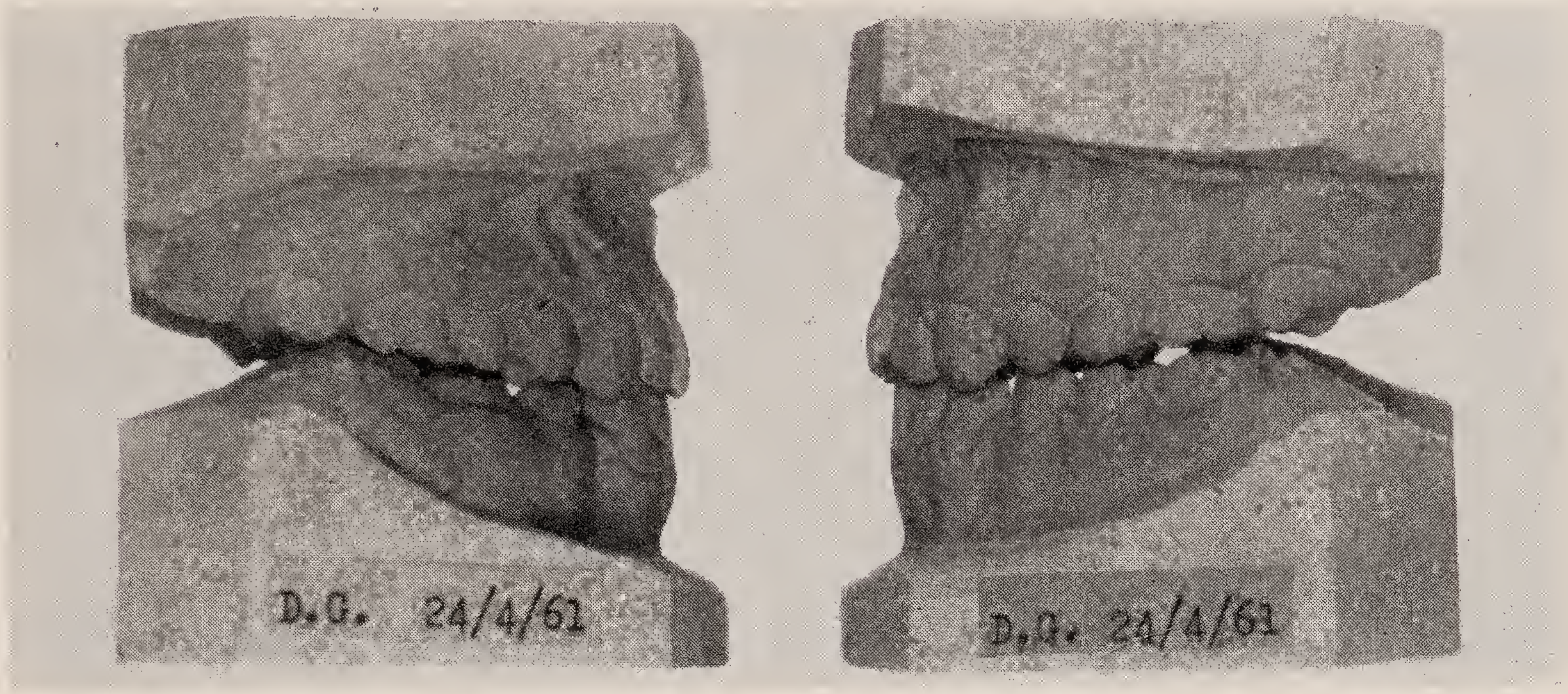


Fig. 3.—Patient D. G., February, 1961. Tracing of lateral skull radiograph.

undergoing orthodontic treatment, entailing loss of lower premolar teeth, was advised by a dental surgeon to undergo hospitalization for removal of impacted lower third molar teeth.

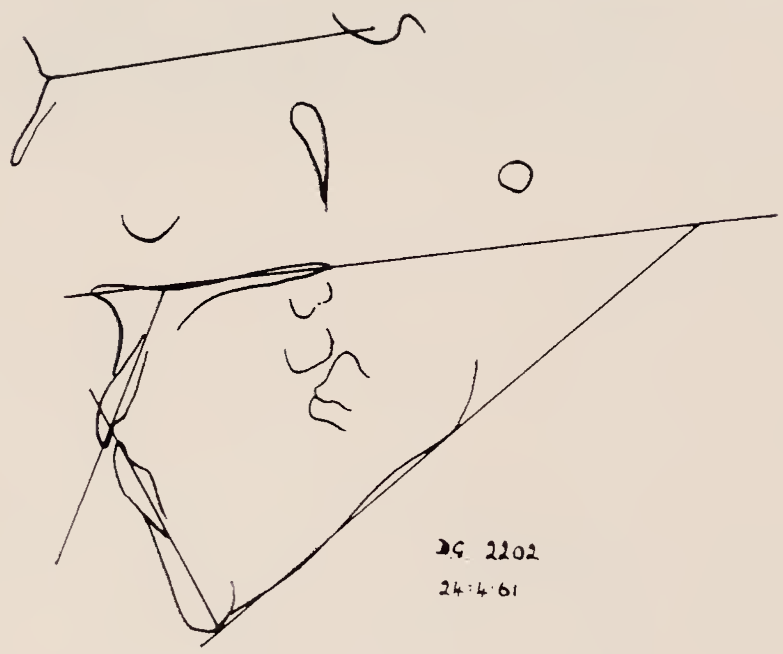
The accepted treatment of lower third molar teeth is surgical removal. This procedure has

been perfected until, at the present time, side effects are minimal. However, the opportunity for jaw fracture, damage to adjacent teeth or transplantation of lower third molar germs to the first molar sockets is carried out (Clarke, 1955; Apfel, 1956). This meets with success



A

B



C

Fig. 4.—Patient D. G., April and June, 1961. A, Record models; B, Tracing of lateral oblique radiograph. C, Tracing of lateral skull radiograph (*see Table I*).

soft tissues, and postoperative infection, still exists.

A technique is available for determining the likelihood of third molar impaction (Henry and Morant, 1936), so allowing a decision to be made regarding removal of lower third molar teeth before symptoms arise.

The extraction of lower second molars to allow accommodation of lower third molar teeth has been advocated and the results analysed (Smith, 1957). The time at which these teeth are extracted is important; if extraction is delayed until lower third molar roots are formed the crowns are liable to tip mesially.

Having regard to the effects of early first molar loss on the position of adjacent teeth, as far as implantation, prevention of tooth drift, and subsequent lower third molar impaction are concerned.

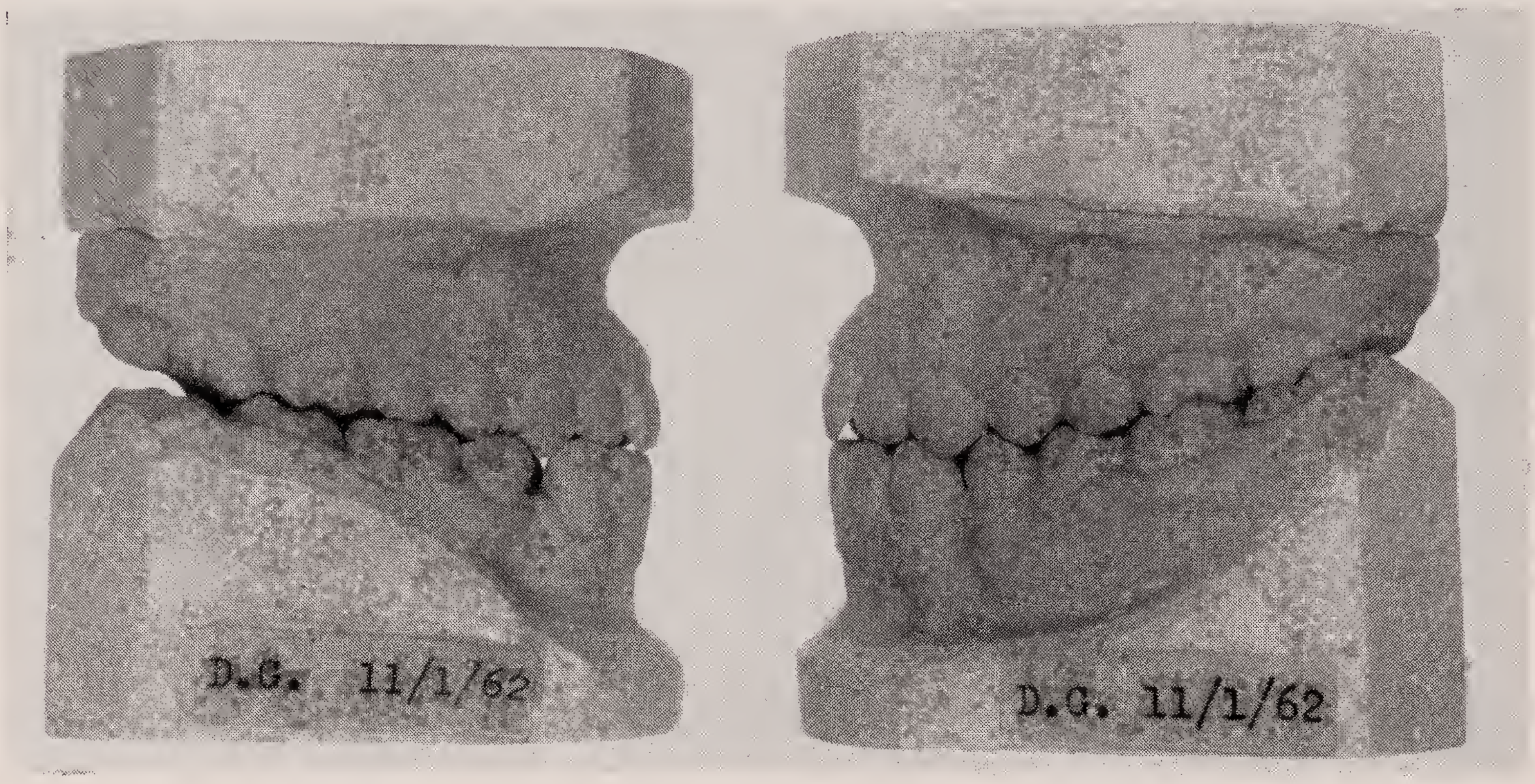
The eruption of lower third molar teeth following orthodontic treatment is known to occur (Broadbent, 1943). In the case shown, lower buccal segments were moved forward using intermaxillary traction, following which the lower third molar teeth erupted into occlusion, no appliance therapy being required to aline these lower third molars.

The case reports which follow demonstrate eruption of lower third molars subsequent to orthodontic treatment being carried out. This treatment included loss of teeth from the lower

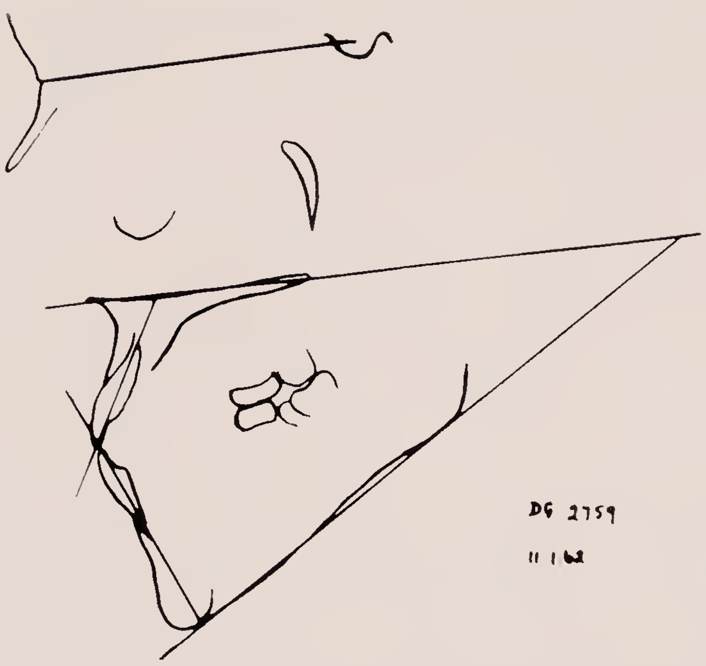
jaw followed by forward movement of the remaining teeth in the buccal segments. It is my contention that this forward movement provided space for lower third molar teeth to erupt and become functional units of the

CASE REPORTS

D. G. 1782 (date of birth, 24 April, 1948).—Diagnosis was carried out on 25 Sept., 1957, when the patient was 9 years of age. All teeth were present in the mouth except for $\overline{|6}$ which had been previously extracted and $\frac{85\,|\,8}{8\quad 8}$ which were unerupted (*Fig.* 1 A, B).



A



B

Fig. 5.—Patient D. G., January, 1962. A, Record models; B, Tracing of lateral skull radiograph.

The upper incisor teeth were proclined relative to the maxillary plane. The lower incisor teeth were retroclined relative to the mandibular plane (*Fig.* 1 C; *Table I*).

The overjet was reversed.

The overbite was reduced.

Centre lines coincided with that of the face.

During mandibular closure there was a forward displacement.

Crowding was present in both upper and lower arches.

There was a normal dental base relation with a maxillary mandibular plane angle above average (33°).

The soft-tissue pattern was one of incompetent lips with a tooth-together swallow accompanied by circumoral muscle contraction. There was normal speech and no sucking habits.

Treatment was aimed at correcting the incisor relationship.

dentition. Otherwise they may remain impacted and require surgical removal at a later date.

All patients undergoing treatment were subjected to a detailed analysis utilizing serial record models, lateral oblique, and true lateral skull radiographs, together with a clinical evaluation. I intend to analyse the first case completely to illustrate the method adopted, but for the sake of brevity will omit the detailed analysis of subsequent cases.

Table I.—CHANGES IN ANGULAR RELATION OF $\underline{1|1}$ AND $\overline{1|1}$ TO MAXILLARY AND MANDIBULAR PLANES DURING TREATMENT

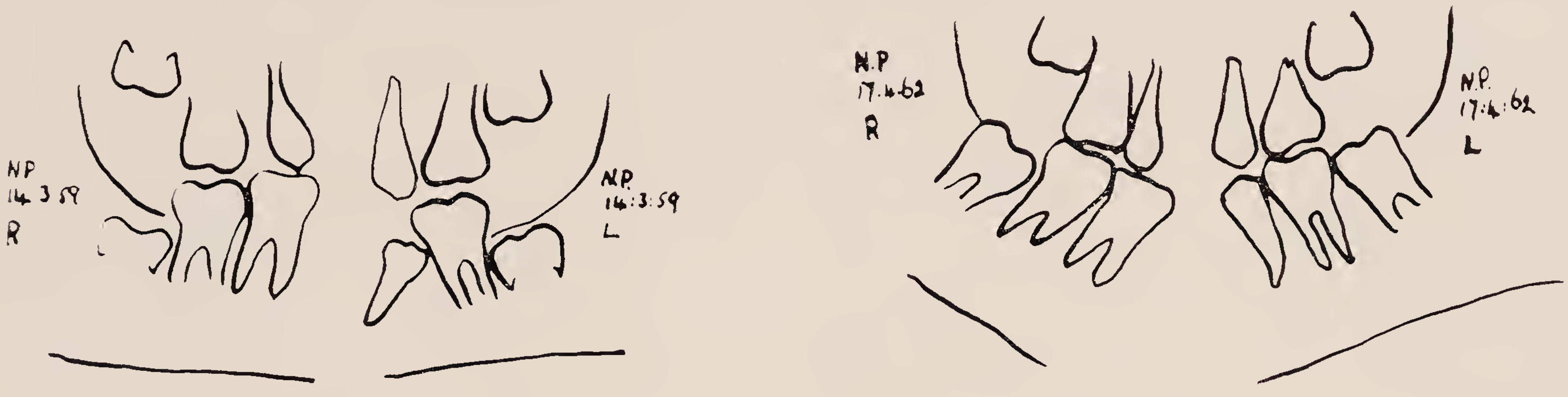
DATE	$\underline{1\|1}$ TO MAXILLARY PLANE	$\overline{1\|1}$ TO MANDIBULAR PLANE
11 Sept., 1957	111°	87·5°
9 Nov., 1959	114°	83°
7 Feb., 1961	112°	83°
24 April, 1961	118°	77°
11 Jan., 1962	119°	80°

Commencing in December, 1957, the upper incisor teeth were proclined using an upper removable appliance, and this was followed by a reverse Andresen (*Fig.* 2).

In May, 1960, $\overline{4|}$ was extracted and a fixed appliance was used to contract the lower arch, so creating space for $\overline{8|8}$ eruption.

In February, 1961, an upper removable appliance was fitted to provide Class III intermaxillary traction (*Fig.* 3). In June, 1961, the incisor relation was satisfactory, the displacing activity having been eliminated (*Fig.* 4).

Appliances were withdrawn in October, 1961 (*Fig.* 5), and a lateral skull radiograph shows the incisor relation



A B

Fig. 6.—Patient N. P., aged 15 years (date of birth, 4 April, 1947). Tracings of lateral oblique radiographs. A, 14 March, 1959; B, 17 April, 1962.

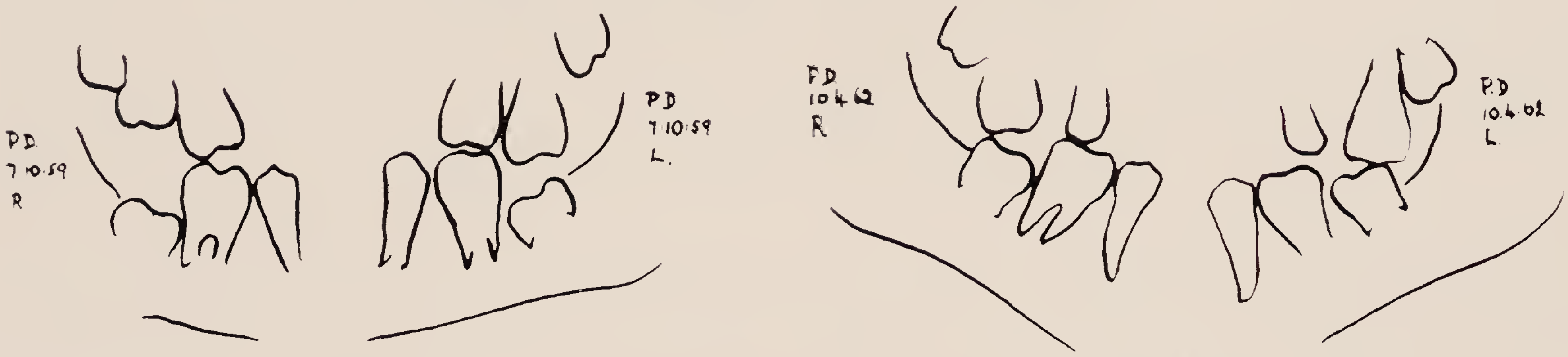


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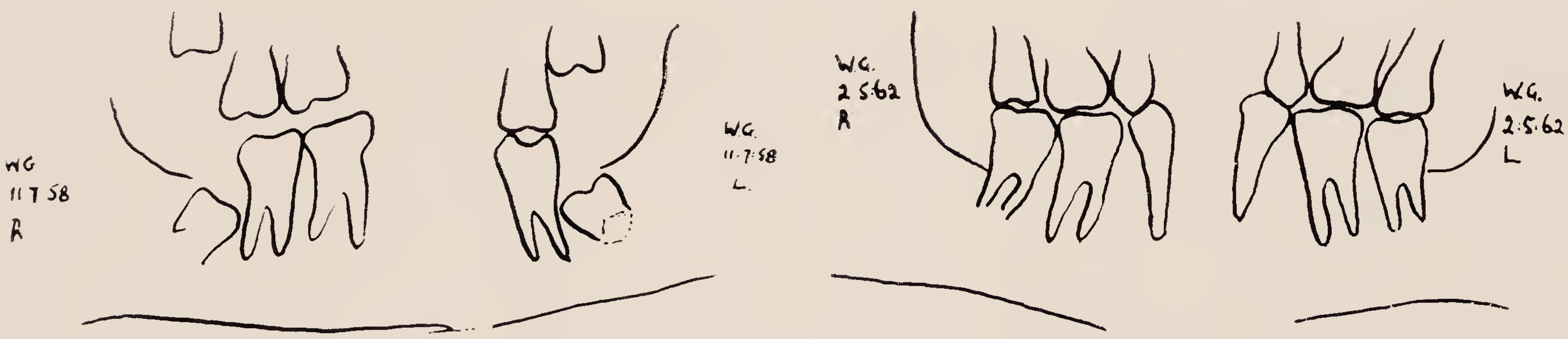
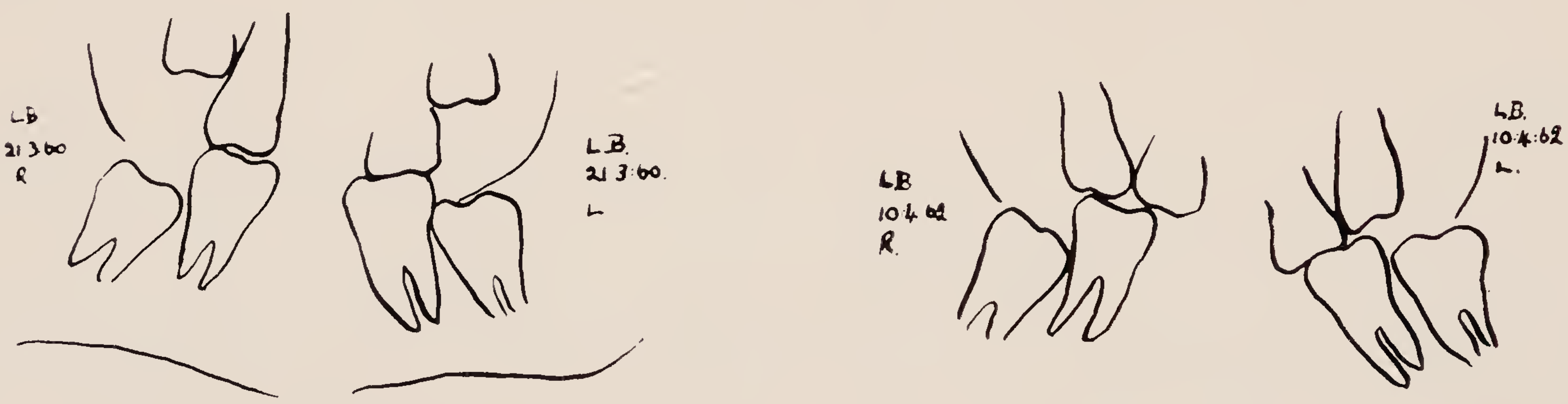
Fig. 7.—Patient P. D., aged 13 years (date of birth, 31 Oct., 1948). Tracings of lateral oblique radiographs. A, 7 Oct., 1959; B, 10 April, 1962.



A B

Fig. 8.—Patient W. G., aged 17 years (date of birth, 22 Aug., 1945). Tracings of lateral oblique radiographs. A, 11 July, 1958; B, 2 May, 1962. ($\overline{8|8}$ eruption had occurred 2 years previously.)



A B

Fig. 9.—Patient L. B., aged 21 years (date of birth, 3 Sept., 1941). Tracings of latera oblique radiographs. A, 21 March, 1960; B, 10 April, 1962.

in January, 1962 (*Fig.* 5 B; *Table I*) since when the occlusion has remained stable.

Radiographs and models illustrate that together with improvement of incisor relation, eruption of lower third molar teeth was accomplished at the age of 13 years. Cuspal interdigitation has been achieved without the use of appliances to aline the lower third molar teeth, and the eruption was in no way troublesome to the patient.

interdigitation with teeth in the opposing arch and also have a tight contact with the lower second molar. The sequelae of eruption previously referred to have been avoided.

The lower third molar teeth erupted between 2 and 3 years after commencement of

A B

Fig. 10.—Patient J. B., aged 16 years (date of birth, 12 April, 1946). Tracings of lateral oblique radiographs. A, 5 Oct., 1961; B, 2 May, 1962.

I will now record briefly (*Figs.* 6–10) other cases in which lower third molars have erupted following orthodontic treatment. Tracings of lateral oblique radiographs taken before and after third molar eruption are shown.

CONCLUSION

The foregoing cases act as illustrations of lower third molar teeth which, although favourably placed for eruption, may not have been accepted into the arch due to lack of space. Orthodontic treatment entailing loss of lower teeth followed by forward movement of teeth in the lower buccal segments provided the required space and so allowed eruption of the lower third molar teeth. These teeth have erupted to gain maximum cuspal orthodontic treatment, and therefore appeared in the mouth in some cases 7 years earlier than would be anticipated, from which might be inferred that orthodontic treatment has stimulated their eruption.

Acknowledgements.—I am most grateful to Mr. J. S. Bailie of the Department of Photography, Liverpool Dental Hospital, for producing the illustrations.

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DISCUSSION

Mr. H. E. Wilson said that in some of the cases illustrated there were unilateral extractions. He asked if there was any difference in the crowding anteriorly on sides where there were extractions, to the sides where there were no extractions. He also asked Mr. Huggins to define 'endogenous postural position'.

Mr. D. F. Glass asked Mr. Huggins how he assessed the probability of impaction of the 'eights'.

Dr. G. B. Hopkin asked Mr. Huggins if, in the first case he had illustrated, he had investigated the extent to which the disimpaction was caused by natural growth of the jaws, as against the effect of extractions. There would be quite an amount of growth in girls between 9 and 13 years of age.

Mr. A. Baker asked if Mr. Huggins had continued his research to take into consideration buccal or lingual rotation of the third molars and whether his treatment would relieve that possible form of impaction.

Mr. B. B. J. Lovius asked Mr. Huggins if all the patients were Skeletal IIIs, and, secondly, whether the chronological age was compared with the dental age.

Mr. T. P. G. McCartney asked whether, in cases where there was no other indication for extraction of lower teeth than possible impaction of the lower third molars, he still would extract the lower teeth. Which teeth would he extract?

Mr. Huggins, in reply, said that in all the cases except the first, which he had shown in detail, there were extractions in the upper arch to compensate for lower arch extractions. In the first case, there was no extraction in the upper arch because the crowding was extremely mild.

In reply to Mr. Wilson, he said that in actual fact all the extractions were bilateral. In some cases, lower first molars and sometimes lower first premolars were extracted. With regard to 'endogenous postural position', he would say that was the position of the mandible when the patient was completely relaxed and at rest. It had been termed 'rest position'.

In reply to Mr. Glass, with regard to assessing the probability of impaction, it was something he wished to investigate further. He had said in the paper that Mr. Bowdler Henry, in conjunction with Mr. Morant, had investigated the probabilities of impaction and put forward a very fine method for it, but he had not used that method in determining whether the teeth would have been impacted.

Regarding the likelihood of the lower third molars causing imbrication of the lower labial segment, it had been suggested by several authorities that they were a causative factor. He could only put the other point of view, that there was also said to be an alteration in the soft-tissue pattern during that same time, the late teenage period, and that could equally well be the cause of the imbrication. He could not give any definite answer to that question.

With regard to the question of how much improvement was due to growth, that was linked to Mr. Glass's question of assessing the probability of impaction. The factor of how much a patient would grow would have to be taken into account when assessing the probability of impaction. He had not analysed the cases thoroughly enough to give a complete answer.

In reply to Mr. Baker, he said that he had not, unfortunately, had that type of case come his way.

Mr. Lovius had asked about the skeletal pattern of the cases. There were two Class III, and one with a normal dental base relationship, and there were two or three postnormal dental base relationships. He had not mentioned that because he thought it would take far too long if he analysed each case individually, but he had all the details.

Mr. McCartney had asked if he would extract merely to disimpact the lower third molars. During the course of orthodontic treatment he had not had a patient referred to him who had lower third molars impacted with an intact and well-alined lower arch.

DETERMINING CONDYLE DISPLACEMENT IN CROSS-BITE CASES

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THE midpoint between the lower incisors (hereinafter designated 'incision') can, in theory, be deflected in any direction within the three planes of space: in the type of patient under discussion the deflexion is mainly lateral; the models were placed in the only possible occlusion, it was found that incision was 9 mm. to the right: $\underline{e|}$ occluded entirely lingual to $\overline{e|}$ (*Fig.* 1). Displacement did not occur initially on the $\underline{e|}$ to $\overline{e|}$ occlusion; close inspection

Fig. 1.—Shows extreme cross-bite in a 9½-year-old girl. The lower midline has been deflected 9 mm. to the right, and $\overline{|6}$ has moved 4 mm. forward. $\overline{6|}$ has not moved much relative to its upper counterpart. In this displaced occlusion $\underline{e|}$ is entirely lingual to $\overline{e|}$.

it is a reasonable assumption that the condyles are also displaced.

It must be taken for granted that none of the patients referred to in this article has sustained injury, so that their displacements are entirely caused by cuspal interference; in other words, shift does not occur until after the first occlusal contact. Nor is the functional imbalance due to adhesions in one of the joints, to unilateral muscle spasm, to structural asymmetry, nor to any possible one-sided pathosis: in short, 'incision' would follow a true midsagittal pathway were the cuspal interference eliminated.

The theme of this article is brought out by quoting the case of Lorna, aged 9½ years, whose dentist practised about eighty miles from the Glasgow Dental Hospital. He sought orthodontic advice concerning her 'cross-bite'. Two weeks before her first appointment he sent models and a wax 'squash-bite'. When showed that the jaw was pushed to the right after $\overline{|c}$ struck $\underline{|c}$. The upper left deciduous canine demonstrated two facets of attrition, (1) normal, on its incisal edge, and (2) abnormal, on its lingual surface; this surface was abraded from incisal edge to gingival margin. When the models were occluded 'free-hand', the abraded pattern showed that $\overline{|c}$ slid over the lingual facet on $\underline{|c}$ displacing the jaw; this was confirmed when Lorna was seen in person.

Occlusion was analysed without recourse to anatomical articulation; I did not know an instrument able to reproduce the complicated pathway of deflexion. Ideally, a device for occlusal analysis should trace the movement of any given point between midline and condyle. To be realistic, however, we have to admit that, so far, no instrument can compete with the well-trained human eye. Unfortunately, the eye cannot penetrate into the joints to

Given at the Edinburgh meeting held on 11 May, 1962.

ascertain the action therein, nor has a satisfactory radiographic technique been developed. The trained eye, on the contrary, can appreciate the three-dimensional deflexion of incision relative to the maxillary teeth. But the day may come when we can calculate the direction and extent of condyle shift using visible data. If the maxillary teeth are regarded as the stationary element (the base-line) and if selected landmarks within the visible portion of the mandible are seen to shift, then surely the condyle positions before and after the displacement will be recordable.

Ingenious methods have been contrived, principally by prosthetists, whereby the condyles are projected back from the visible part of the jaw (the teeth); although the condyles are obscured by overlying tissues, their rotational axis—the so-called terminal hinge-axis—can be determined by methods which are described in modern prosthetic journals.

The instrument which is the subject of this article is an attempt to determine the shift of three basic landmarks in the mandible: (1) right condyle, (2) left condyle, and (3) incision. These landmarks are located first, before displacement, and secondly, after displacement; the shift can then be measured. No attempt is made to trace the pathways of the three points which may be tortuous; for the present study it was felt that two positional relationships were needed—(1) the beginning of the movement and (2) its end.

In Lorna's case, incision had closed on a midsagittal path until ⌈c engaged ⌊c; here deflexion began, and this was the first position to be registered; the second was the deflected occlusion with the teeth clenched. As I see it, these positions can be reassumed by the patient with fair accuracy.

The point of departure (first position) was determined as follows: incision had closed on a midsagittal track until ⌈c contacted ⌊c. This relationship was designated 'replacement', because the jaw was restored to its true relationship with the cranium at the moment before deflexion began.

Hereafter the terms 'replacement' and 'displacement' will be used.

In preparation for Lorna's first visit, a flat-topped occlusal plane was constructed of wax, pressed firmly on to the lower model; when hard, it was scraped until the cusps and edges were showing through; with this guard in position, the 'bite' was raised to the minimum consistent with unlocking the occlusion. With the cuspal interference thus neutralized it was observed that the jaw did not displace laterally. Palpation had previously shown that condyle translation was free and symmetric; it was conclusive, therefore, that interference was responsible.

CENTRALIZING THE MIDLINE

Now that we had established that the deflexion was caused by occlusal malfunction, the next step was to register the relationship just before deflexion occurred. At first sight, one might think of using the wax bite-rim already made, softening it in the flame and asking the patient to squash through it. In my opinion, this method is not accurate enough. In the first place, the wax may not be softened uniformly, with the mandible guided off the straight on less-softened lumps. Secondly, with wax overlapping the teeth, the view would be obscured; the contact on the cuspal interference would not be seen and we may, in fact, record a displaced relationship. The task, therefore, was to disclose visibly the registration of occlusion just before the cuspal interference came into operation. In the case here reported this was done in the following manner:—

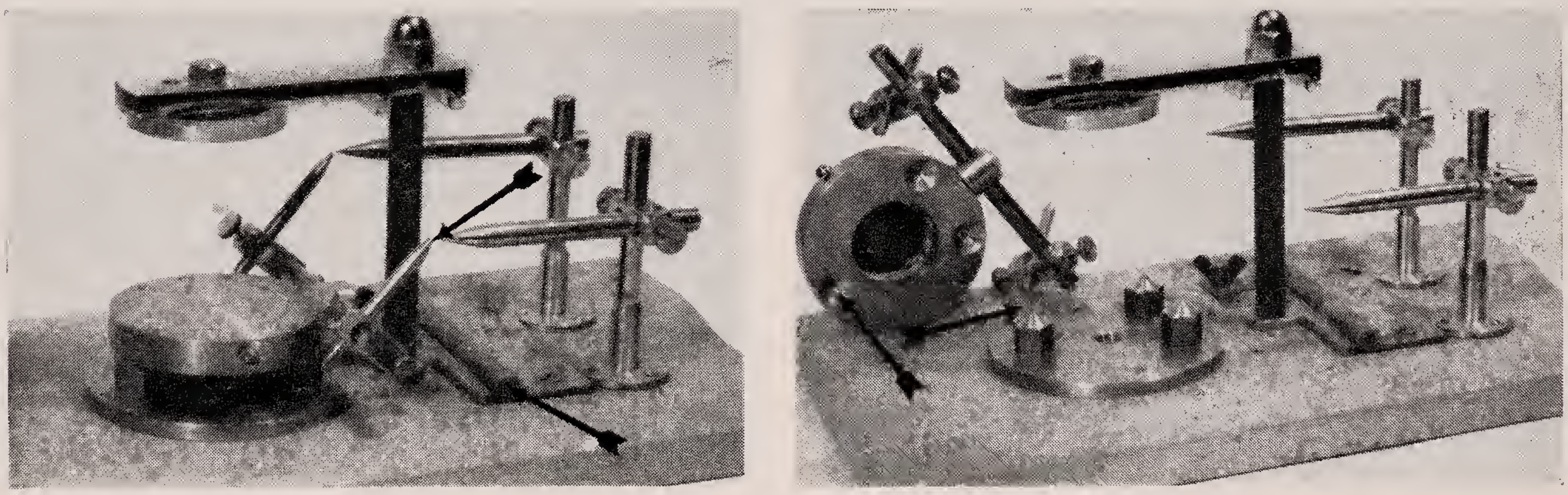
A small piece of blue inlay wax was softened and pressed around ⌈c and an adjacent tooth (for stability). When the wax had hardened, it was scraped down, leaving a bare 1 mm. over the incisal edge. The little wax cap was then placed in position and the young patient asked to close gently, stopping when she felt a tooth meeting the wax. Needless to say, this is not a complete registration of occlusion; an arch-to-arch relation is required, but the inlay-wax cap is the first step. With the wax in position, another small portion was pressed securely on to the first, and trimmed neatly. In this manner a little rim of wax was added to the first, ensuring that the lower teeth

were guided into the same position on subsequent closures.

With the little wax cap on $\overline{|\text{cd}}$ and the occlusion in 'first light contact', the next step was to register occlusion as a whole. This was done by pressing a mix of plaster into the off. The models were now assembled 'freehand' in displaced occlusion.

In other similar cases we have duplicated the models, and have mounted pairs on plane-line articulators, one set representing replacement and the other displacement.

Fig. 2.—The mandible can assume a centric relationship when cuspal interference is neutralized. $\overline{|\text{c}}$ slid up the lingual surface of $\underline{|\text{c}}$ and pushed the jaw to the right in the clenched relationship. The illustration depicts replacement, in contra-distinction to *Fig.* 1 which depicts displacement.



A B

Fig. 3.—Shows an out-dated instrument for determining the shift of the condyles after cross-bite displacement. When cuspal interference is neutralized with a 'wax-bite', the vertical dimension is opened slightly. In this relationship the lower model has been plastered on to a heavy brass base which sits on a tripod of cones. The text describes how the tips of condyle indicators are located in true anatomic relationship with the occlusal plane. Then the rearmost rods are placed tip-to-tip with the condyles: this records the position of the condyles in replacement to be contrasted later with displacement. The wax-bite is removed after swinging back the upper member: when the butterfly-nut is screwed up again fixing the upper member, the lower model can be lifted up into displacement. In A the upper arrow points to the condyle markers, and the lower arrow indicates the hinge. In B the arrows show a cone, and a recess which will drop on to the cone.

interocclusal gap with a dental cement spatula. When set, the wax-plaster 'bite' was withdrawn from the mouth, the models placed in it and mounted on a plane-line articulator. The upper member of the articulator having been previously oiled, the model was slipped

Lorna's replaced models were now taken in the hand; using a ruler, three pencil lines were drawn from upper to lower (*Fig.* 2): one line was near the front, one in the left molar region, and one in the right. The purpose of these pencil lines was to record the relationship

of lower teeth to upper just before displacement. When the upper model was slipped off and set in displaced occlusion, the lower pencil marks were seen to be changed relative to the upper; the lower midline mark was now 9 mm. to the right of the upper mark, the lower left had moved forward 4 mm., and the lower right had hardly moved at all in its relationship to the upper (*see Fig.* 1).

The implication is that as the mandible shifted on the cuspal interference, it screwed around in a sort of Bennett movement; the left mandible came forward, the middle sector swung to the right, and the vertical axis of this horizontal shift was located somewhere through upper right second permanent molar to its lower counterpart. One is reluctant to accept these data because the right condyle had displaced inwards, which is not credible, considering the bone structure medial to the human condyle.

Our knowledge of condyle displacement would be extended if we had a reliable instrument able to measure the displacement. The instrument described here is an attempt at such a device. *Fig.* 3 shows an earlier model.

Three brass cones sat on the base-plate: when the models were in replaced relationship, that is to say, when the bite was opened enough to cancel out cuspal interference, the cones fitted into three concave recesses in a heavy brass plate carrying the lower model; gravity held the recesses on the cones. When the brass plate carrying the lower model was lifted off the cones, the bite could be closed up into displacement. Theoretically, when released, the lower model would always drop into identical position. Unfortunately, as an engineer, I am not sufficiently accurate: I could not line up the cones and recesses with enough precision to eliminate a wobble. The present instrument makes use of the knife-edge principle; when the lower model is dropped from the displaced relationship to the replaced—which is tantamount to opening the bite a little—the heavy brass plate carrying the lower model slides into the exact position on knife-edges (*Fig.* 4).

I do not suggest that this type of instrument should be in daily use in dental practice, but it might prove interesting in the hands of the research worker.

The first step in the technique is to project the midpoint of each condyle from the teeth. Using the principle of triangulation in the three dimensions, we work backwards. If this

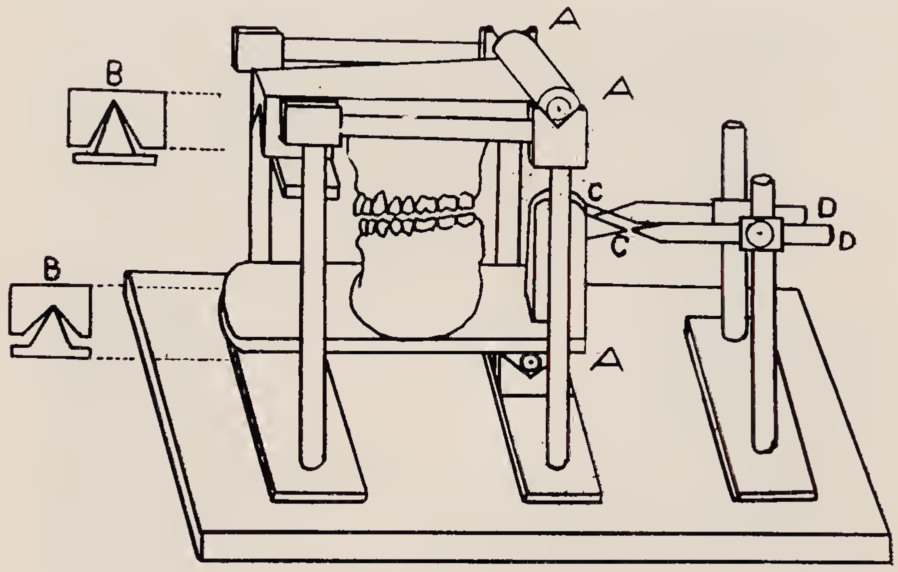


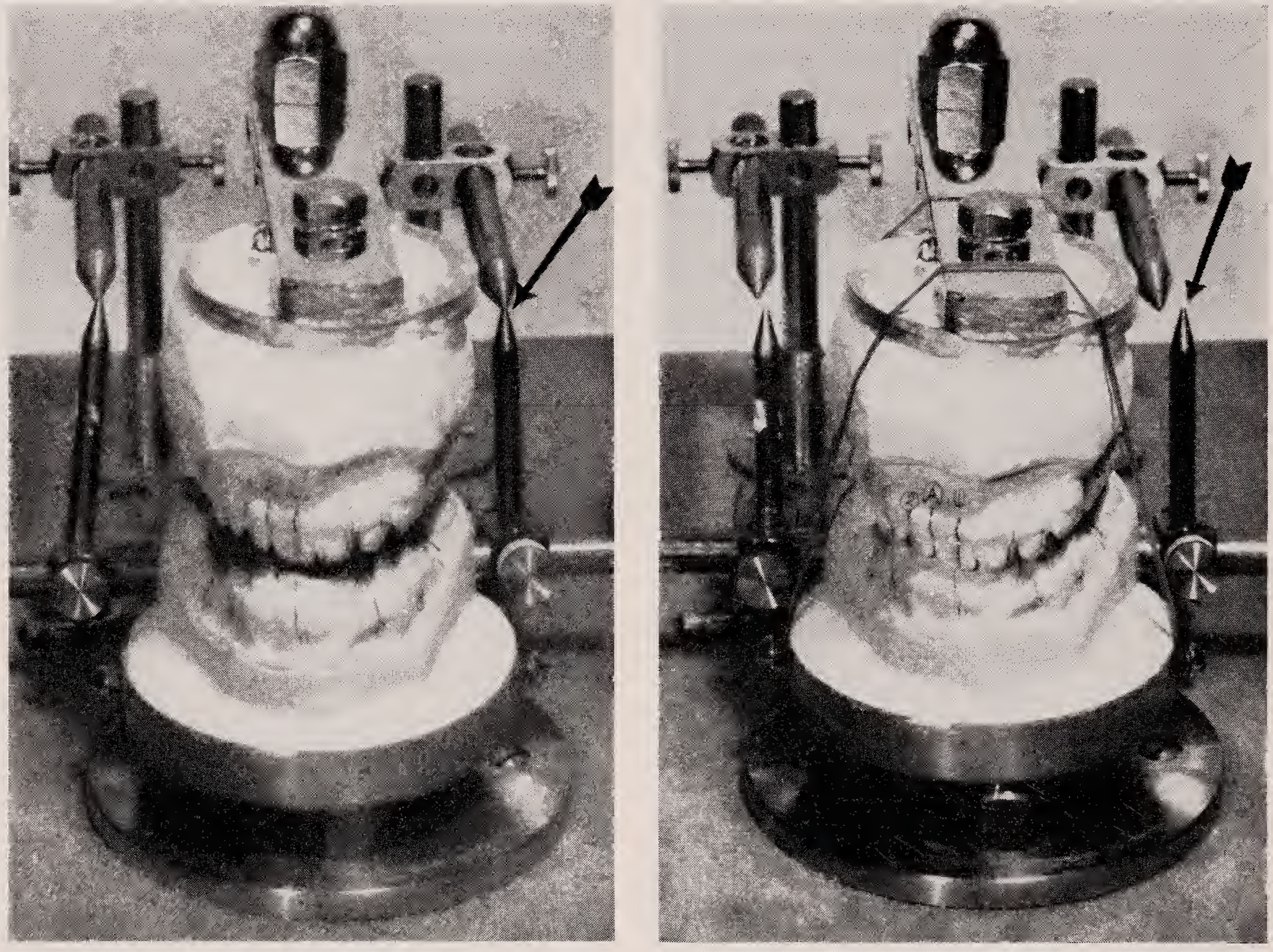
Fig. 4.—This diagram represents a newer type of instrument. The heavy brass plates carrying the upper and lower models locate themselves precisely on their respective knife-edges (A, A, A, A, and B, B). The wax-bite can be removed with greater ease. C and C show diagrammatically where the condyle midpoints may lie relative to the lower occlusal plane. When the jaw is in its replaced position, the second pair of pointers are brought from the rear and fixed tip-to-tip with the condyle indicators. (*See also Fig.* 5.)

could be done exactly, we could determine the rotational centre of each condyle, sagittally and medially, and the distance between; these imaginary points would be related to incision and to the occlusal plane.

Space precludes description of the technique for locating these points and the so-called 'terminal hinge-axis', but the technique can be found in numerous artieles in modern prosthetic literature; for example, Ulf Posselt and Victor Sears have referred to it on several occasions.

For the sake of brevity, let us assume that we can position the tip of a brass pointer on the midpoint of each condyle (*Fig.* 4 C, C). Further, let us concede that the condyle midpoints are properly related from incision and, indeed, from every other part of the occlusal plane. It should not be necessary to say that the condyles are in fixed relationship with the lower occlusal plane, but not with the upper.

Now that we have successfully manœuvred the two brass pointers into position, indicating where the condyles lie when they are replaced, we can now shift the occlusion into displacement and observe the change in the position of the pointers. The detail of the change is more easily recognized if a second pair of pointers are brought into action: *Fig.* 5 A shows the pointers tip-to-tip, prior to the shift, and *Fig.* 5 B demonstrates how they have changed in Lorna's cross-bite. I need not say that the second pair of brass pointers are mounted on fixed posts seen at the rear of the apparatus; they can be moved universally and locked tip-to-tip with the condyle midpoints, no matter where the latter lie. The second pointers thus act as a 'memory' to show us where the first pair were sited before cross-bite.



A B

Fig. 5.—This figure depicts the older instrument, first, with the replacing wax in the interocclusal space. Secondly, it shows the change in condyle position, when the wax is removed and the lower model lifted up off its locating tripod into the displacement caused by cuspal interference.

Reverting to Lorna's case, $\underline{e|}$, $\underline{|c}$, and $\overline{|c}$ were recommended for extraction in the anticipation that displacement might cease when the cause was removed. Of course, the muscles might have become conditioned to hold the mandible to the right. Therefore, to aid centralization a resilient monobloc (polyvinyl chloride) was constructed to replaced relationship, three plaster teeth having first been trimmed off the model, the appliance to be worn during sleep.

It would be futile to rely too much on a centralizing monobloc alone: when the jaw has been displaced during a period of eruption and growth, the teeth will probably erupt or drift into ectopic position, so that balanced occlusion does not necessarily follow. In due course, a functional bite-analysis will be made and orthodontic treatment initiated.

DISCUSSION

Mr. H. E. Wilson congratulated Dr. Campbell. He, himself, was basically a clinician. Measurements were fine; they were necessary for research to find out function and so on, but when it came to examining a particular patient, one found that the difference in position of the condyle was so small that it could not be measured, and the symptoms were out of all proportion to the degree of displacement. He knew Dr. Campbell agreed because they had discussed it before. The clinician must not be led to believe that he could not do any clinical work unless he had some sort of complicated apparatus to measure condyle shift.

Dr. Campbell said that he and Mr. Wilson had talked about the subject before and were thoroughly agreed. He did not want to surround himself with anatomical measurements and gadgets, but in the training years of a person taking up the work one of the best ways to train his eye was to have him doing it on an anatomical articulator. Once a young man had trained his eye he could put the anatomical articulator on the top back shelf, and it was the best place for it.

THE SURGICAL CORRECTION OF CERTAIN BITE ANOMALIES WITH PARTICULAR REFERENCE TO THE MAXILLARY APPROACH

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As is well known, certain cases of gross malocclusion do not respond to conventional methods of orthodontic treatment, and resort to surgery has got to be made. The classic example is probably the severe Class III relationship where one thinks in terms of mandibular ostectomy or osteotomy, but today I am concerned with the maxillary approach rather than the mandibular, about which sufficient publicity has already been given.

I suppose, historically, the maxillary approach, in so far as this country is concerned, dates from the last war, when many unreduced, but malunited, fractures of the middle third of the face were seen. It was found possible to expose the fracture lines and to perform refracture and a secondary reduction in many of these cases. In particular, this applied to the Guerin's fracture, where the tooth-bearing segment had sheared off the antral superstructure and was pushed back and up to produce an open-bite type of deformity.

The immediate application of this principle was apparent in the infra-occlusion of cleft palate, certainly as it concerned the collapse of the lateral segments, particularly in those bilateral cases where the premaxilla ceased to function as a corner-stone in the arch.

Fig. 1 shows such a case, one of the few but typical examples of early and misguided surgery, where no consideration had been given to the ultimate fate of the maxillary arch—the motto being 'close at all costs', with, in this instance, a multiplicity of operations.

There is an atrophic premaxilla carrying a supernumerary tooth, with the segments collapsed anterior to the first and second molar region where the buttress of the malar prevents any great degree of distortion. It will be noted that the upper canines tend to approximate and the arch is converted from a U to a V in shape.

The distortion of the upper arch is reflected in the soft tissues (*Fig.* 2), giving the middle third of the face a pinched and overclosed appearance, which is always associated with an infra-occlusion of this nature.

In regard to the models shown in *Figs.* 3 and 4, these demonstrate quite clearly the degree of shift of the lateral segments that must be obtained before near occlusion can be achieved. It is quite obvious that no orthodontic treatment, even rapid expansion, can bring this about, and resort to surgery must be made despite the fact that the cleft is partially reinstated in the anterior third, demonstrating, incidentally, the shortage of tissue which must be present.

Surgically, it is necessary to approach the maxilla as though this were an unreduced Guerin's fracture, and mobilize both lateral segments, dividing the palatal repair quite deliberately in order to achieve sufficient freedom to manipulate the two halves into the appropriate occlusion.

This will necessitate, in this type of case where a bilateral osteotomy is performed, immobilizing the mandible in the first instance to a plaster cap, and reducing the maxillary components to their opposite counterpart. Later, intermaxillary fixation can be released and the immobilization transferred to the maxilla alone.

The result of this operation is apparent in *Fig.* 5 and again in *Fig.* 6, with the patient wearing a denture. It is also apparent in the full face represented in *Fig.* 7 to show how prosthesis and surgery have combined to make a not inconsiderable improvement.

Given at the Edinburgh meeting held on 11 May, 1962.

Anterior open bite also poses a problem in regard to orthodontic treatment, particularly when the patient has reached adolescent or adult years. Although many operations have been suggested for this deformity, to my mind the best approach is a maxillary one.

Some years ago Professor Schuchardt suggested that the lateral segments could be

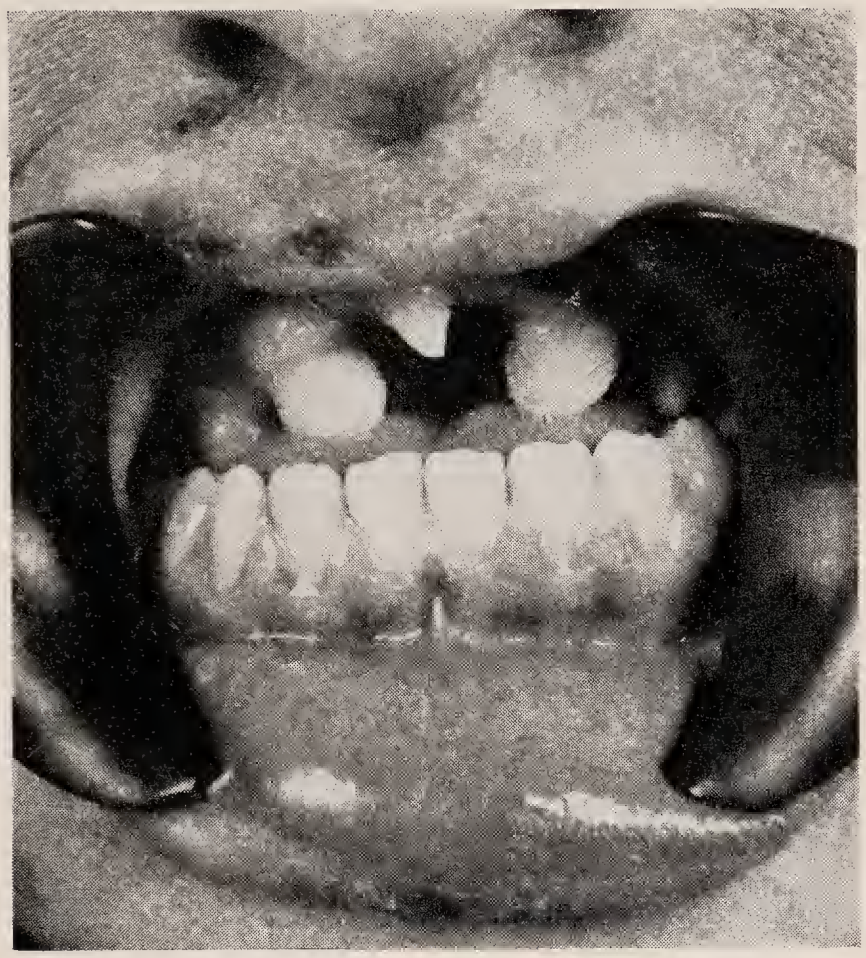
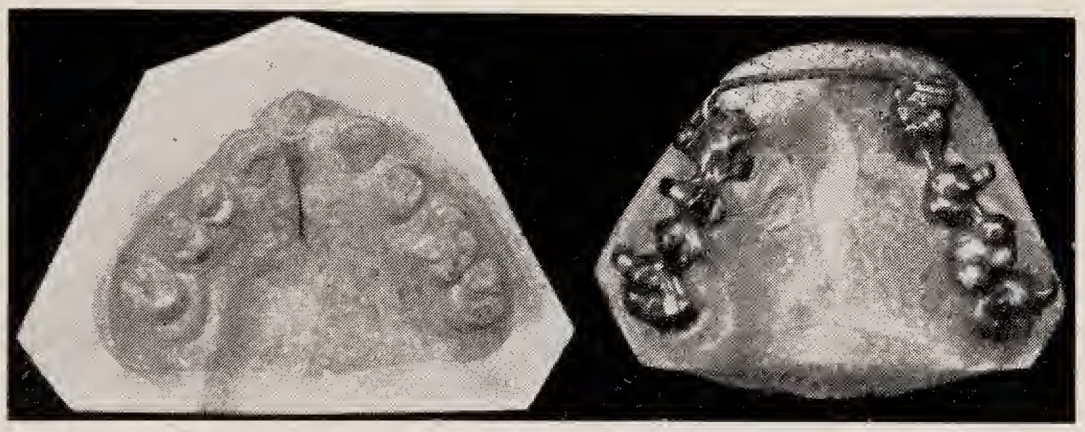


Fig. 1.—*Case* 1. Collapsed maxillary segments with an atrophic premaxilla.

Fig. 2.—*Case* 1. Patient aged 16 years, prior to surgery.



A B

Fig. 3.—*Case* 1. A, Model of upper arch. B, Model with cap splints, and lateral segments re-positioned.

Fig. 4.—*Case* 1. Postoperative model.

Fig. 5.—*Case* 1. Photograph to show occlusion obtained.

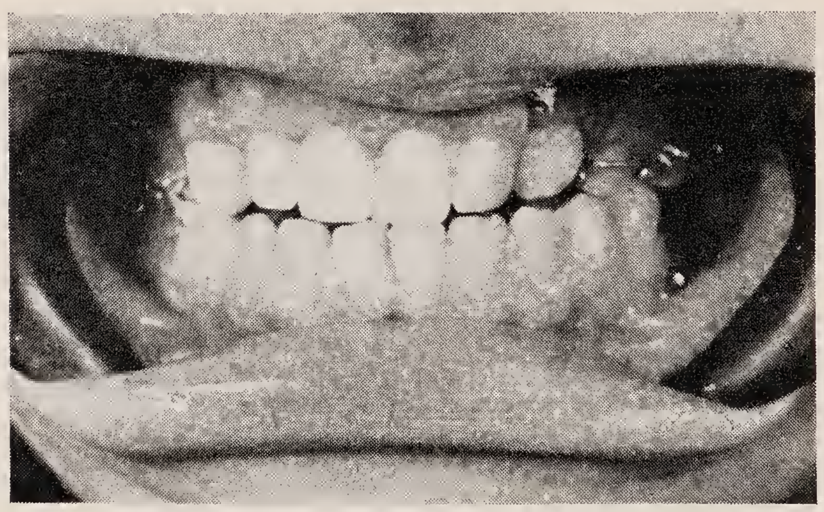


Fig. 6.—*Case* 1. Partially reinstated cleft occluded by prosthesis.

reduced upwards, as is illustrated in the diagram shown in *Fig.* 8.

Osteotomy is performed, with or without the sacrifice of one of the premolar teeth, by a two-stage procedure with an interval of 21 days. In the first stage, a palatal flap is raised and an osteotomy performed through the palatal bone and tuberosity (*Fig.* 9).

The second-stage procedure is via a buccal approach, in which an ostectomy involving the anterior wall of the antrum is completed.

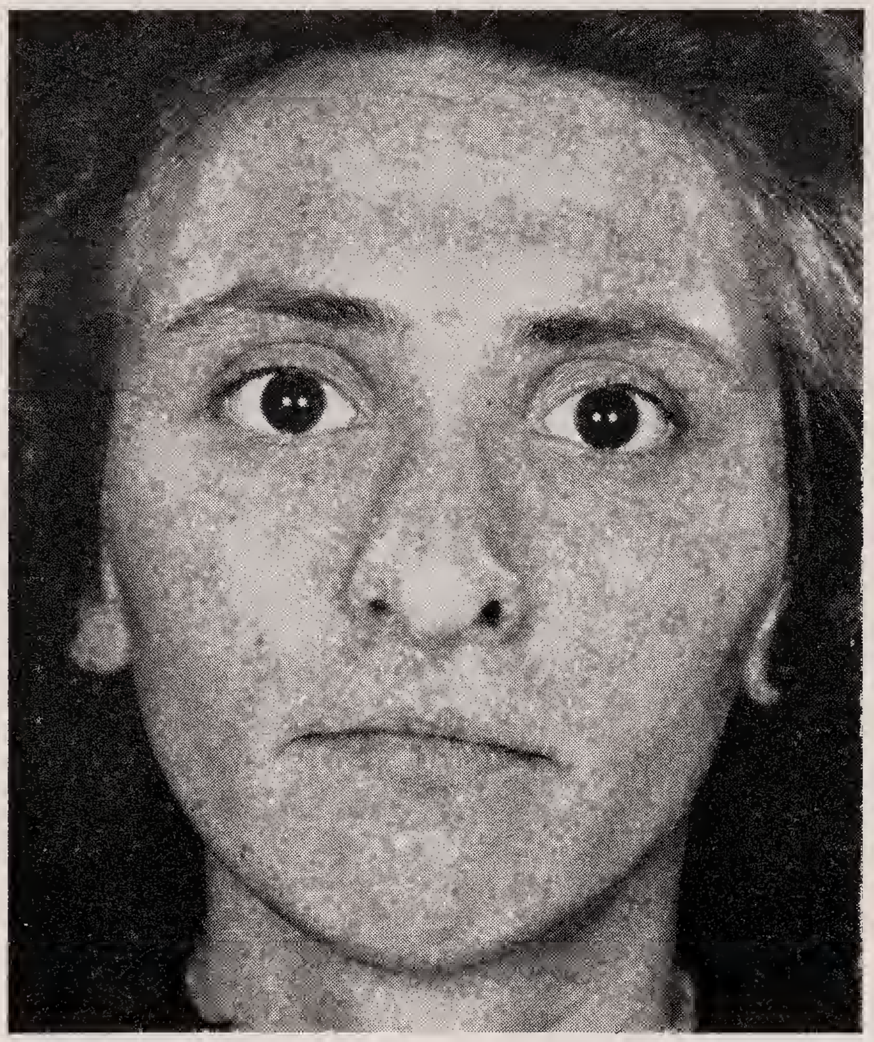


Fig. 7.—*Case* 1. Postoperative facial appearance.

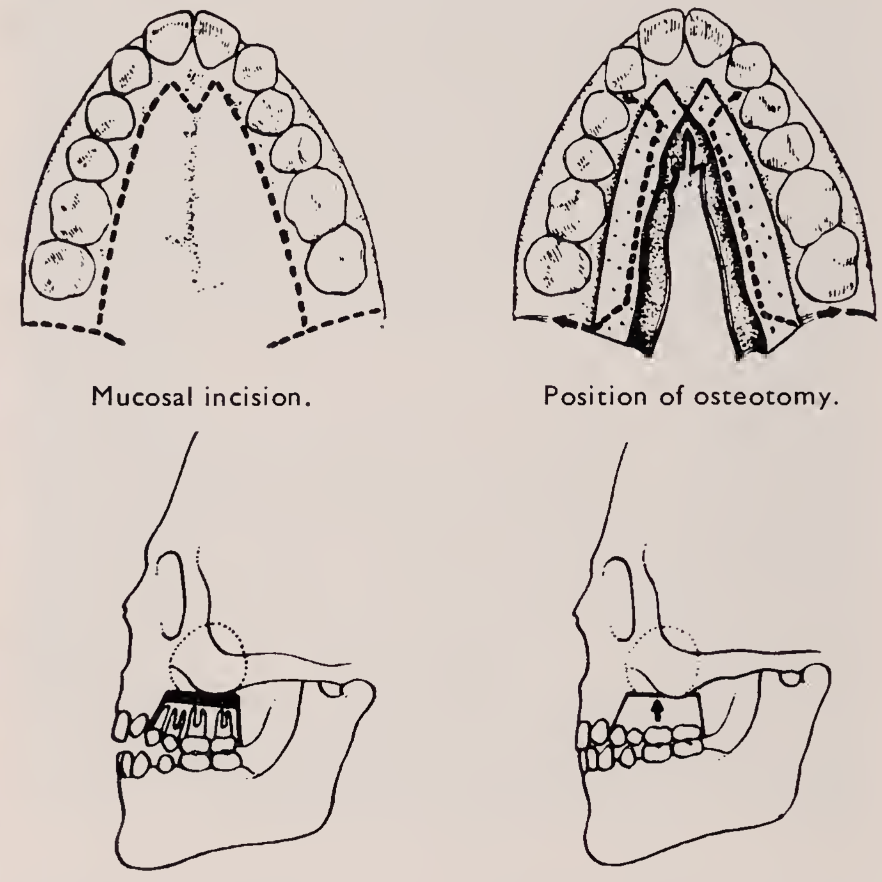


Fig. 8.—*Case* 2. Diagram of Schuchardt's procedure.

Fig. 9.—*Case* 2. Type of flap used indicated by sutures still in position.

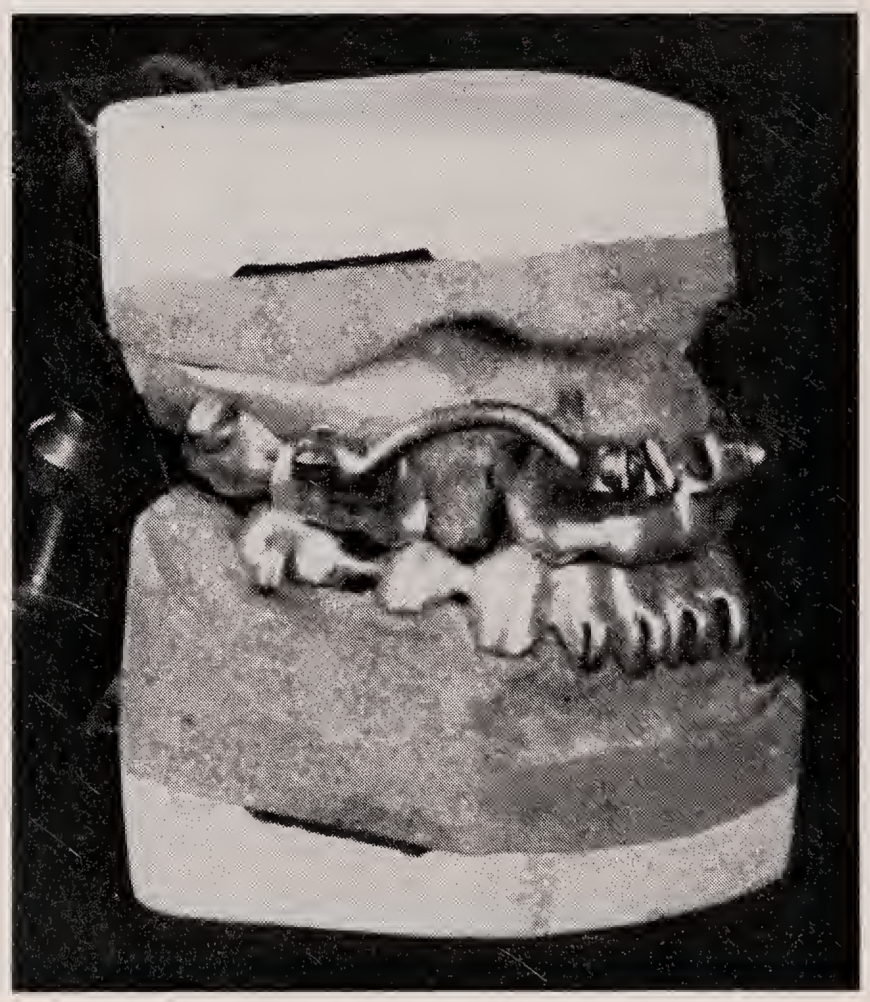


Fig. 10.—*Case* 2. Cap splints with locking bar omitting the first premolars.

After suitable cap-splints have been applied (*Fig.* 10), the operative procedure is completed by tapping up the lateral segments and

Fig. 11.—*Case* 2. Preoperative photograph of the occlusion.

Fig. 13.—*Case* 3. Preoperative photograph of the occlusion.

Fig. 15.—*Case* 3. Postoperative result with partial dentures inserted.

immobilizing them to the mandible. Subsequently, the intermaxillary fixation is released and reliance is placed on two locking bars, with the premaxilla as the fixed point.

Fig. 11 shows the patient's occlusion before operation, and in *Fig.* 12 after operation. Although an ideal result has not been produced, the improvement is noticeable and the ability to masticate much improved.

The third case presented would be assessed as quite impossible to treat either prosthetically or by orthodontic means.

Fig. 13 shows the occlusion without the unsatisfactory dentures the patient had been used to wearing, and demonstrates how the

Fig. 12.—*Case* 2. Postoperative result.

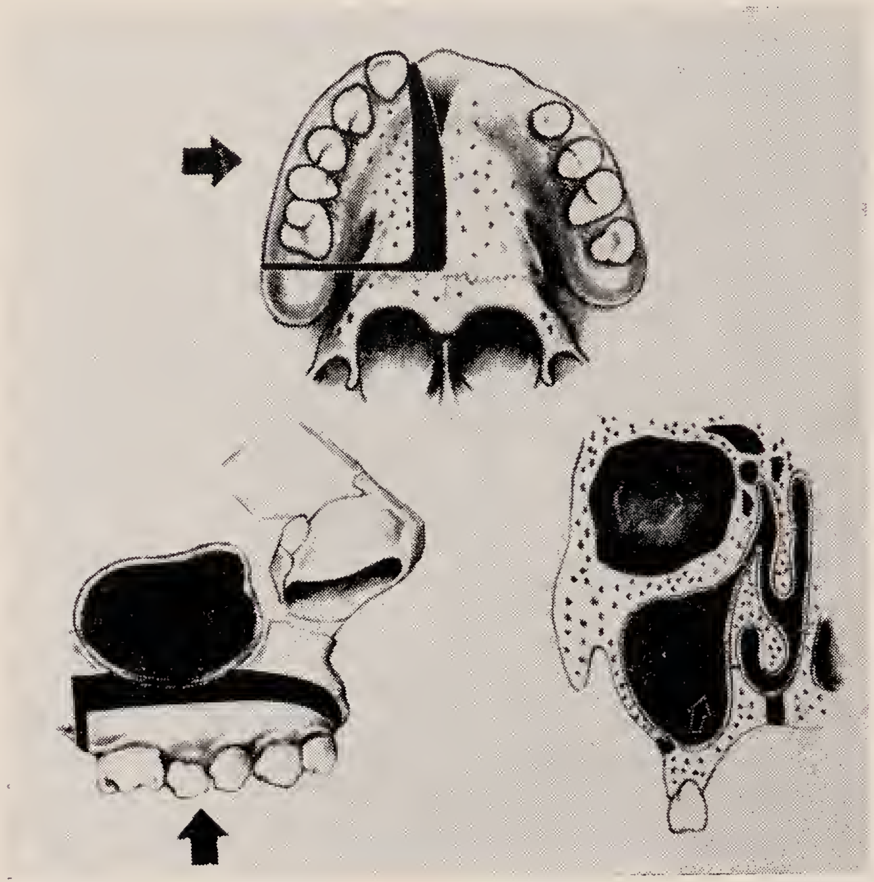


Fig. 14.—*Case* 3. Diagrammatic representation of the ostectomy.

upper teeth in the right maxillary segment occlude.

The principle of the operative procedure is shown in *Fig.* 14, whereby a buccal and palatal ostectomy was performed, removing a measured amount of bone so that the segment from $\underline{|6}$ to $\underline{|2}$ could be shunted both upwards and inwards.

Again, a two-stage procedure was undertaken with previously designed cap-splints maintained for 6 weeks to produce the occlusion which is demonstrated in *Fig.* 15, with the patient wearing a new upper and lower denture.

CONCLUSION

In conclusion, although many such cases are amenable to orthodontic treatment, some present such a gross deformity that this is impossible, or are left too late for treatment by conventional means. Another approach has to be considered, and, in the author's opinion, the rather neglected maxillary surgical attack should not be omitted from the orthodontic armamentarium.

DISCUSSION

Mr. D. F. Glass said that he was very interested in the work because some of the cases were well beyond orthodontic treatment.

He did not entirely understand the first case; the bilateral cleft. Had Mr. Henry opened the two lateral sections of the maxilla surgically or dental orthopaedically before stabilizing with the silver-capped splint?

The cases with the V-shaped palatal clefts were common. He was interested to note what a fine nose the girl had. He wanted to know why she had such a good nose and such a poor mandible–maxilla relationship.

It would be interesting to know what Mr. Henry found was the end-result of altering the position of the mandible in the second case; that is, of altering the amount of accommodation for the tongue, which Mr. Glass thought might have caused the anterior open bite.

Another thing which interested him was the moving of the lateral segment of the maxilla, the buccal segment, inwards and upwards: what kind of body union would he get. Did they unite? Also, did the teeth live or die?

Mr. Cradock Henry said that the first case was put on merely to illustrate the fact that what they had learnt in the war could be applied to congenital abnormalities, particularly of cleft palate.

With regard to the nose, it was a good one. He suspected that she was operated upon in the early days of the war. She had, at some stage, a secondary operation for lip improvement which was combined with a nasal improvement.

With regard to the second case of anterior open bite, it was most fortunate; in that particular case, the boy did not have a very large tongue. In another case of anterior open bite which he had operated on by the same method, though there was a large tongue, relapse occurred to some extent anteriorly because of the size of the tongue.

In the third case, he would like to make it clear that firm union had been established without any resort to bone-graft. There was a long period in which there appeared to be considerable sensory loss, but regeneration had occurred, the teeth were definitely vital, and there was no suggestion of their having become permanently devitalized.

Mr. D. M. Menezes said that he had read in recent German and American literature about expansion of the upper arch by splitting the median palatal suture, and he asked Mr. Henry's views on that.

Mr. Cradock Henry said that he did not really have a view about it. The literature should be known to him but it was not. He would be interested to read it.

Mr. L. M. Irwin asked if there was any difference in the voice after the operation.

Mr. Cradock Henry said that there was, in the last two cases, no difference. In the first, he thought, if anything, the voice was not improved; it might have become a little worse.

Mr. C. D. Parker referred to the second case and asked if there was any change in the posture of the mandible postoperatively, judged by the amount of freeway space. Secondly, how long after the operation was the photograph taken?

Mr. Cradock Henry said that the photograph on the screen with the splints in position was an immediate postoperative photograph, and that with the splints removed was about six months after operation.

Mr. C. D. Parker said that Mr. Glass had raised a point about changing the posture of the mandible. Did Mr. Henry relate any change in the freeway space to the amount of bone he had removed from the maxilla?

Mr. Cradock Henry said that he did not think the relationship of the mandible with the maxilla had virtually changed at all.

Dr. G. B. Hopkin asked if Mr. Henry had any experience or views on the surgical correction of gross anteroposterior anomalies of the maxilla.

Mr. Cradock Henry said that his experience was only slight, but he had seen other people's work in cases of cleft palate. It was a formidable procedure. There was an element of risk in moving a segment of the maxilla of that size, in which the blood-supply must have been considerably disturbed, any very great distance.

Mr. S. Haynes asked if Mr. Henry differentiated between those cases which were suitable for maxillary resection and those suitable for mandibular resection? In the second case, the patient had a very high Frankfurt–mandibular-plane angle and he would have thought a mandibular resection would have been more suitable.

Mr. Cradock Henry said that he thought that many of the cases were quite suitable for mandibular surgery. There was, however, one great advantage of maxillary surgery and that was that the immobilization required was probably shorter, and there was far less discomfort entailed to the patient.

Mr. H. G. Watkin said he had been interested to hear Mr. Henry speak about resection of the tongue. He himself had done seven or eight cases, and they had all been very successful. He wondered if Mr. Henry had done any reducing of the size of the tongue when it was too big?

Mr. Cradock Henry said that he personally thought that tongue reduction had a very great place in surgery, both mandibular and maxillary, because the tongue was undoubtedly responsible for a relapse in the vast majority of those cases.

Mr. A. Baker asked if Mr. Henry preformed the connecting bar of the precision locks?

Mr. Cradock Henry replied that it was done in the laboratory and preformed.

Mr. A. Baker said that Mr. Henry had said that he had doubts as to the viability of the flap. Why had he chosen that particular approach and not done a push-back with the central incision?

Mr. Cradock Henry replied that it was a helpful and welcome suggestion because, as a further operation, he would do a push-back without question. In fact, the palate had survived perfectly well, but it gave rise to a certain amount of concern in the early hours, when it had looked rather blue.

ADAPTIVE FUNCTIONAL DIFFERENCES IN TWINS

By P. M. BENZIES, B.D.S., D.D.O. R.F.P.S., D.ORTH. R.C.S.
Registrar to the Dental Department for Children, Guy's Hospital

DENTAL malocclusion in twins is an interesting line of investigation. Brash (1929) states: 'It is no less certain that a detailed assessment of differences in the occlusion of monovular twins provides the best hope of being able to determine the influence which may be exercised by environment as the complement of the genetic constitution.'

One of the more recent of these studies in this country showed monozygotic twins who had differing malocclusions (Leech, 1955). These twins tended to show how a slight variation in the morphology, resting postures, and behaviour of the lips could either lead to a Class II, division 1 or a Class II, division 2 malocclusion.

Townend (1950) has described monovular twins in which thumb-sucking caused an open bite in one twin, while the other twin, having no such habit, had a more normal incisor relationship.

Lundstrom (1948, 1951) and Kraus, Wise, and Frei (1959) have compared the dental and craniofacial differences between a considerable number of fraternal and monovular twins and triplets.

Allan (1961) has described the effects of loss of the lower first molars in one twin, comparing this with the other twin who had not lost any teeth.

McKeag and Scott (1956), referring to differences in fraternal twins, state that when they occur they are probably due to 'genetic or internal factors altering the balance between gene action and cytoplasm response'. An obvious example is where there is some hormonal imbalance.

It is important to remember that the majority of monovular twins have almost identical occlusions.

MONOVULAR TWINS

The similarity of twins in itself does not prove that they are monovular. Newman, Freeman, and Holzinger (1937) postulated nine points by which monovular twins could be assessed. For example, they must be strikingly similar and their hair, eye colour, iris patterns, texture, and colour of skin must be similar. They should have the same facial

Table I.—A COMPARISON OF THE FACTORS FOUND IN THE BLOOD OF THE TWINS AND THEIR PARENTS. (THERE ARE ONLY THREE VARIABLE FACTORS, i.e., MN, RHESUS, AND D.)

	FATHER	MOTHER	LINDA	SUSAN
Blood group	O	O	O	O
MN factor	MS Ns	M MS	MS Ns	MS Ns
Rhesus factor	CDe/cde	CDe/CDe	CDe/cde	CDe/cde
V factor	Negative	Negative	Negative	Negative
K factor	Negative	Negative	Negative	Negative
D factor	Positive	Negative	Negative	Negative
L factor	Negative	Negative	Negative	Negative
P factor	Negative	Negative	Negative	Negative
Secretion of ABH in saliva	Nil	Nil	Nil	Nil

Table II.—THE METHOD OF CALCULATION OF THE PROBABILITY OF BOTH MONOZYGOUS AND DIAZYGOUS TWINS. (THESE FIGURES INDICATE A 92 PER CENT LIKELIHOOD OF MONOZYGOUS TWINS AND 8 PER CENT LIKELIHOOD OF DIAZYGOUS TWINS, BY APPROXIMATION.)

Estimated chance of diazygotic twins in this family	0·70	Estimated chance of monozygotic twins	0·30
Chance of diazygotic twins being of same sex	0·5	Chance of monozygotic twins being of the same sex	1·00
Same ABO group	1·0	Same ABO group	1·0
MNS	0·50	MNS	1·0
Rhesus	0·50	Rhesus	1·0
Duffy	0·50	Duffy	1·0
	0·02625		0·30

Relative chance of diazygotic twins: monozygotic twins—0·02625 : 0·30

Probability that these twins are diazygotic

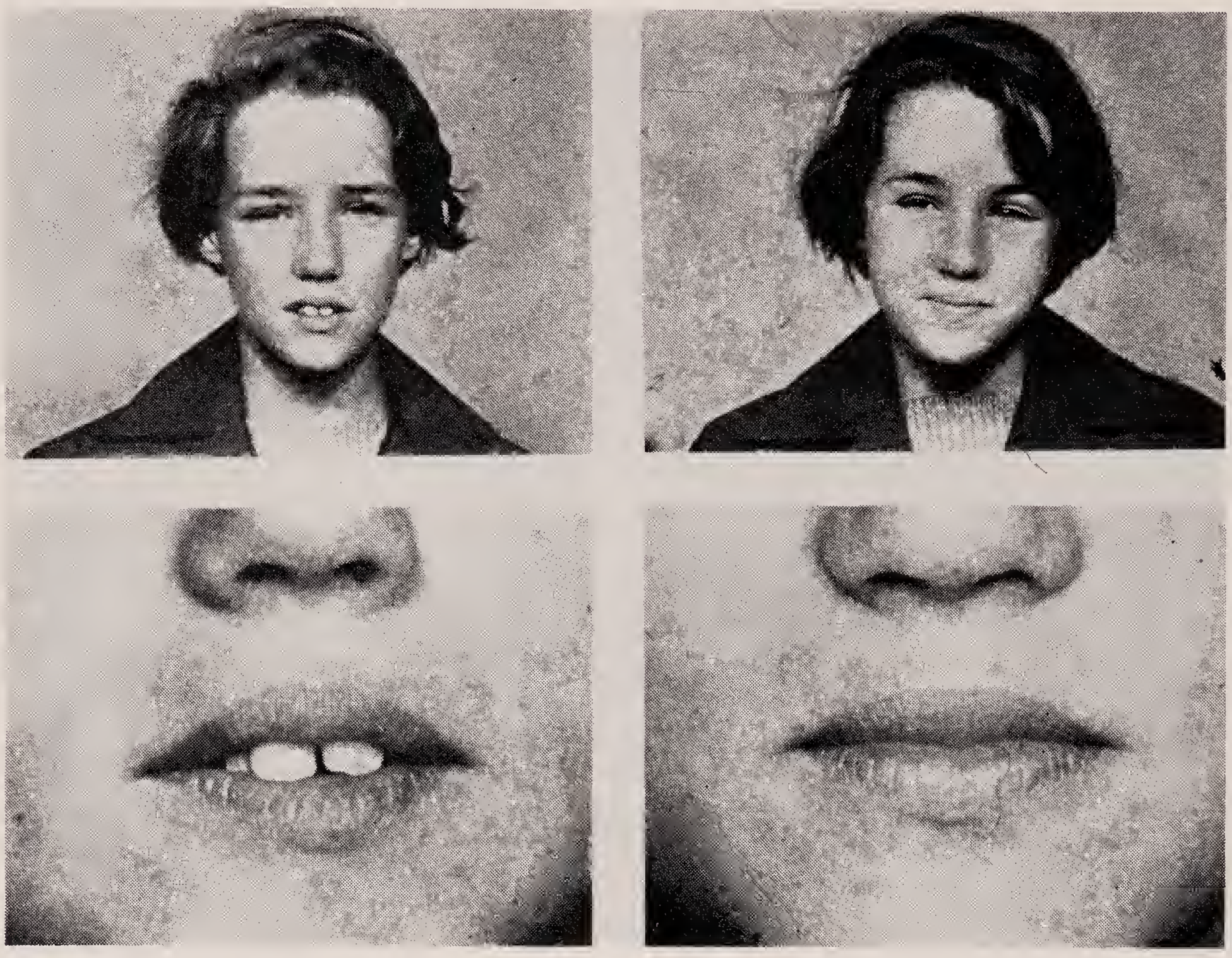
$$\frac{0{\cdot}02625}{0{\cdot}30+0{\cdot}02625} = 0{\cdot}0805$$

Probability that these twins are monozygotic

$$\frac{0{\cdot}30}{0{\cdot}30+0{\cdot}02625} = 0{\cdot}9195$$

Given at the Edinburgh meeting held on 12 May, 1962.

features. Their hands and fingers should be similar, with a likeness in the palm and finger prints. The point noticed in these twins is that the likeness of the prints of one right-hand set of finger prints was more like the other twin's left-hand prints than her own left-hand prints or her twin's right-hand prints. They both had a unilateral facial asymmetry of the same side and the twins both had the same degree of dental hypoplasia. The filling patterns were the same, and they did conform to the postulates.



L. S.

Fig. 1.—Extracted cine frames of the twins. Twin S. on the left and twin L. on the right showing, *above*, full face and, *below*, close-up of the lips in their commonest habitual position.

Other methods of investigating the identical nature of twins are the blood-pictures, which do not give absolute proof, but give a strong indication as to the likelihood of monovular or fraternal twins.

Table I shows the comparison of blood-factors found in the twins and in their father and mother. From this information is calculated the likelihood of their monovular and their fraternal nature. These results show a relatively strong possibility of their monovular nature. This is then worked out mathematically and the result shows that there is a 92 per cent likelihood that these twins are monovular and only an 8 per cent likelihood that they are fraternal (*Table II*).

The evidence from the analysis of the lateral skull radiographs confirms that the skeletal relations of twin S. and twin L. are so similar that they could be considered monovular twins. From the results of Prorok

Table III.—A Comparison of the Differences between the Twins, using Prorok's Standards from the Lateral Skull Radiographs

Lateral Skull Angles	Fraternal Standard	Monovular Standard	S. and L.
Bo—Go—Gn	6·11°	2·83°	1·0°
Bo—S—N	5·43°	4·14°	1·5°
Bo—N—Po	4·43°	1·74°	0·5°
Bo—N—Tip of $\underline{1\|}$	4·20°	2·42°	1·5°
Bo—N—A	4·13°	2·42°	0·5°

(1958) (*Table III*) the twins show that the differences in their skeletal measurements and, in particular, the angle between the Bolton current infection). In the twins under discussion it was decided that the similarity between them was such that it was not

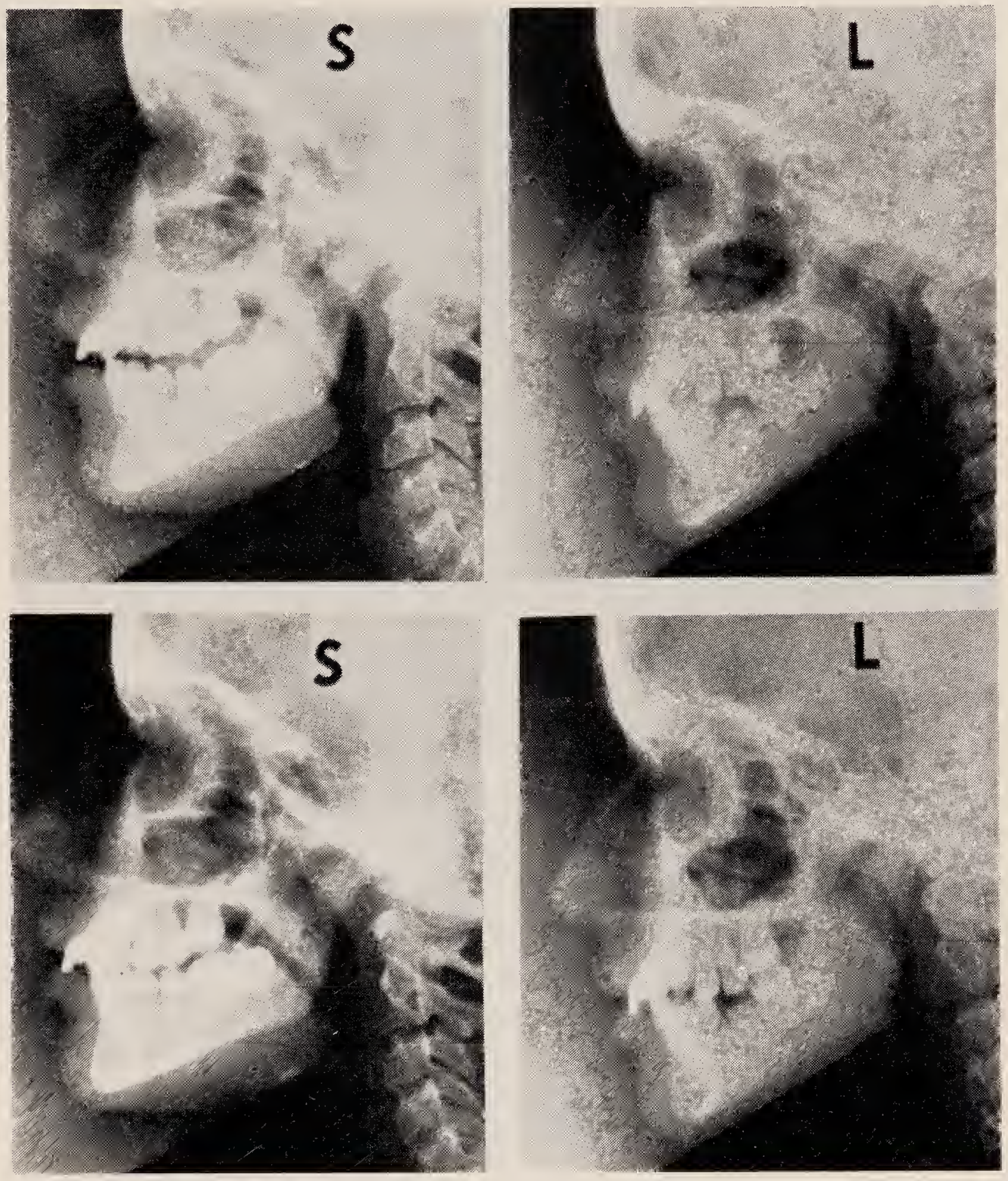


Fig. 2.—Lateral skull radiographs of the twins, twin S. on the left and twin L. on the right. The upper pictures show the rest positions and the lower pictures show the teeth in occlusion. Twin L.'s lips part in occlusion.

point, nasion, and the tip of the maxillary central incisor, put their variations well inside the standard deviation for monovular twins compared to the fraternal twins variation.

One absolute proof to indicate monovular twins is to do reciprocal skin grafts from one twin to the other. The subsequent success of these grafts indicates that they are identical twins. The failure of the grafts would indicate fraternal twins (provided there was no inter-

desirable to perform skin grafts to attain this proof. There was positive medical evidence that the twins had a common placenta.

It was felt that the skeletal relation and soft-tissue morphology at rest were so similar that even if these were not identical twins, the evidence is sufficiently interesting to publish. The twins have a slight variation in the behaviour of the lips and postural position of the mandible which may account for the differing malocclusions (*Figs.* 1, 2).

At birth twin S. weighed 7 lb. and twin L. weighed 6 lb. 8 oz. The twins were aged 11 years 9 months at the first examination. Twin S. was 5 ft. 3 in. and twin L. was 5 ft. $2\frac{1}{2}$ in. in height. Twin S. was 6 st. 3 lb. and twin L. was 6 st. 2 lb. in weight. Both are right-handed and speak in the same way with a very slight lisp. The forwards and thus reduces the need for such lip effort (*Fig.* 5). The electromyogram at rest shows a relative reduced activity in twin L.'s masseter muscles. Neither twin S. nor twin L. posture their mandibles downwards and forwards in swallowing; the mandible is retruded into near occlusion. In twin L. the lower lip is to be found in contact with the upper lip in an habitual oral

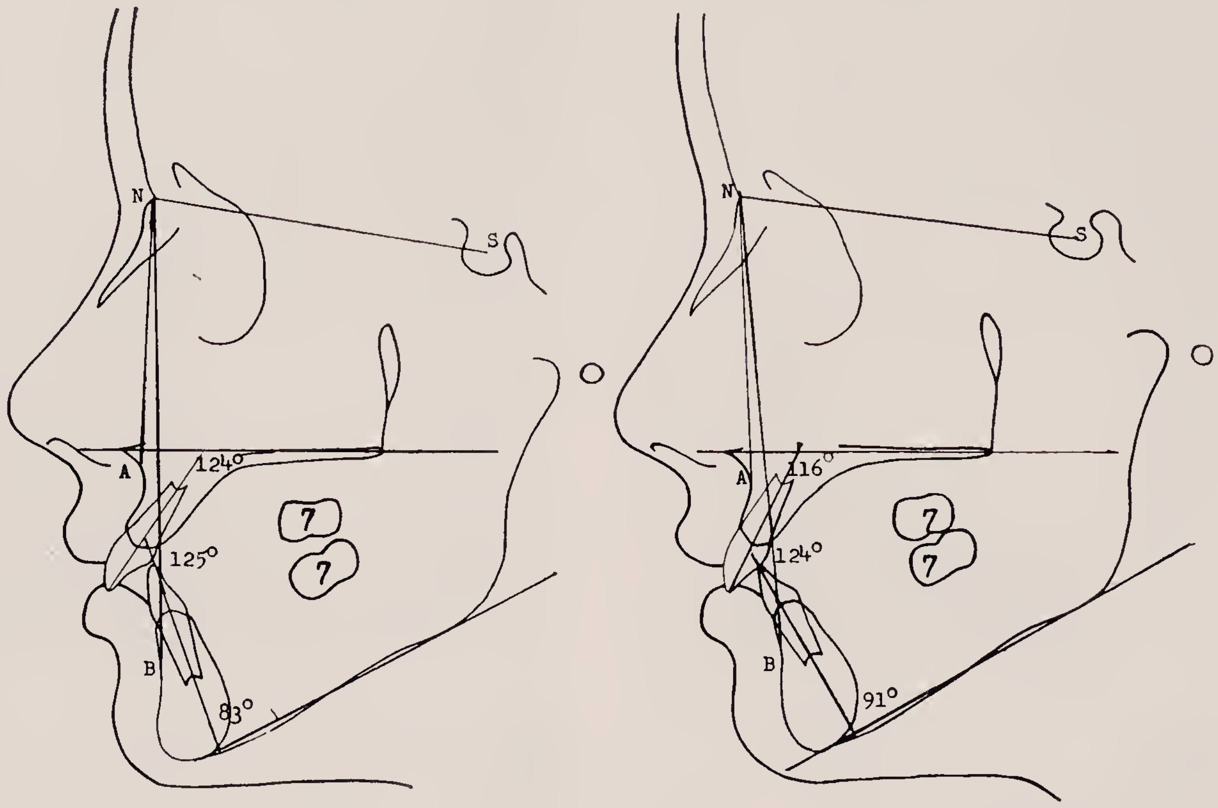


Fig. 3.—Tracings from the lateral skulls; the second molars have not erupted fully into occlusion.

freeway space was 3 mm. for twin S. and 2 mm. for twin L., presumably because of the forward posture of the mandible.

Skeletal Relationship.—The skeletal form is shown in *Fig.* 3:—

Max. mand. plane angle	29°	for twin L.
Max. mand. plane angle	28°	for twin S.
SNA angle	81°	for twin L.
SNB ,,	78°	for twin L.
ANB ,,	3°	for twin L.
SNA ,,	82°	for twin S.
SNB ,,	79°	for twin S.
ANB ,,	3°	for twin S.

Both twins therefore have a normal anteroposterior relationship of the dental bases.

Soft Tissues.—The lips have an identical morphology—if the twins are carefully compared it is not possible to demonstrate any difference in the upper lips at rest, either in length or fullness. Similarly, no difference in the morphology of the lower lip can be demonstrated at rest. Each twin has to effect an oral seal by contracting the circumoral muscles. However, twin L. maintains an habitual lip seal in her commonest facial expression and in speech, and twin S. leaves her lips apart in her commonest facial expression and in speech.

In the maintenance of anterior oral seal with the lips, twin L. tends to posture her mandible downwards and forwards (*Fig.* 4). It is notable from the electromyograms taken with the lips held together that twin S. has greater muscular activity than twin L., presumably because she does not posture her mandible downwards and forwards, and thus requires greater efforts to maintain an oral seal than twin L. who does posture her mandible seal. The indentations of the upper incisors are to be found on the inside of the lower lip. She does posture forward just prior to her swallow.

Twin S. in swallowing allows her lower lip and tongue to touch momentarily—the lip being caught under the upper incisors, there being a tooth-apart swallow. The lower lip is to be found tucked into the upper incisors, with indentations from the upper teeth found nearer the middle or crest of the lower lip vermilion, maintaining the anterior oral seal. The upper lip exposes upper incisors. Twin S. shows a consistent earlier eruption time than twin L. by about 3 to 6 months.

Occlusion.—They both had Class II, division 1 malocclusions with a history of loss of upper and lower first molars. In both cases there must have been an element of crowding before the loss of the first molars (*Fig.* 6). In twin S. the Class II relationship was more marked than in twin L. (*Fig.* 7). The degree of overjet in twin S. was 7 mm. and in twin L. 4 mm. The anteroposterior relationship of the buccal segments of twin S. was just *over* half a unit Class II on both sides, and the anteroposterior relationship of the buccal segments of twin L. was just *under* half a unit Class II on both sides. Twin S. lost the lower 6's at 8 years and the upper 6's at 10 years of age. Twin L. lost all the 6's at 10 years of age. The mother did say that twin S. tended to mouth breathe and leave her lips apart after whooping-cough at $4\frac{1}{2}$ years of age. Dummies were sucked until 2 years of age. Neither twin had any upper respiratory tract disease. In ability and temperament they are very alike, although their mother has the impression that twin S. is slightly more expressive than twin L.

Treatment.—In both cases treatment consisted of simple removable appliances with Adams cribs on $\underline{4|4}$ to

reduce the overjet until $\underline{7|7}$ and $\overline{7|7}$ erupted. When $\underline{7|7}$ erupted bands were made on $\underline{754|457}$ and tubes were soldered on to sectional arches attached to these teeth. The cheek teeth were then retracted to Class I relation, with cervical traction fitting on to buccal tubes on the sectional arches. The labial bow was eventually altered to a free-sliding bar to retract $\underline{21|12}$ in both cases. It was decided to use this method to see whether the behaviour pattern of either twin would modify spontaneously throughout treatment. The use of an activator or Norwegian plate would have predisposed to twin S. acquiring a forward posture, though it would not have been the ideal treatment for twin L. Up to the present, that is one year of treatment, there has been little modification in the behaviour of either twin, although the overjets have improved. However, there is a tendency for twin L. to lose her forward posture behaviour.

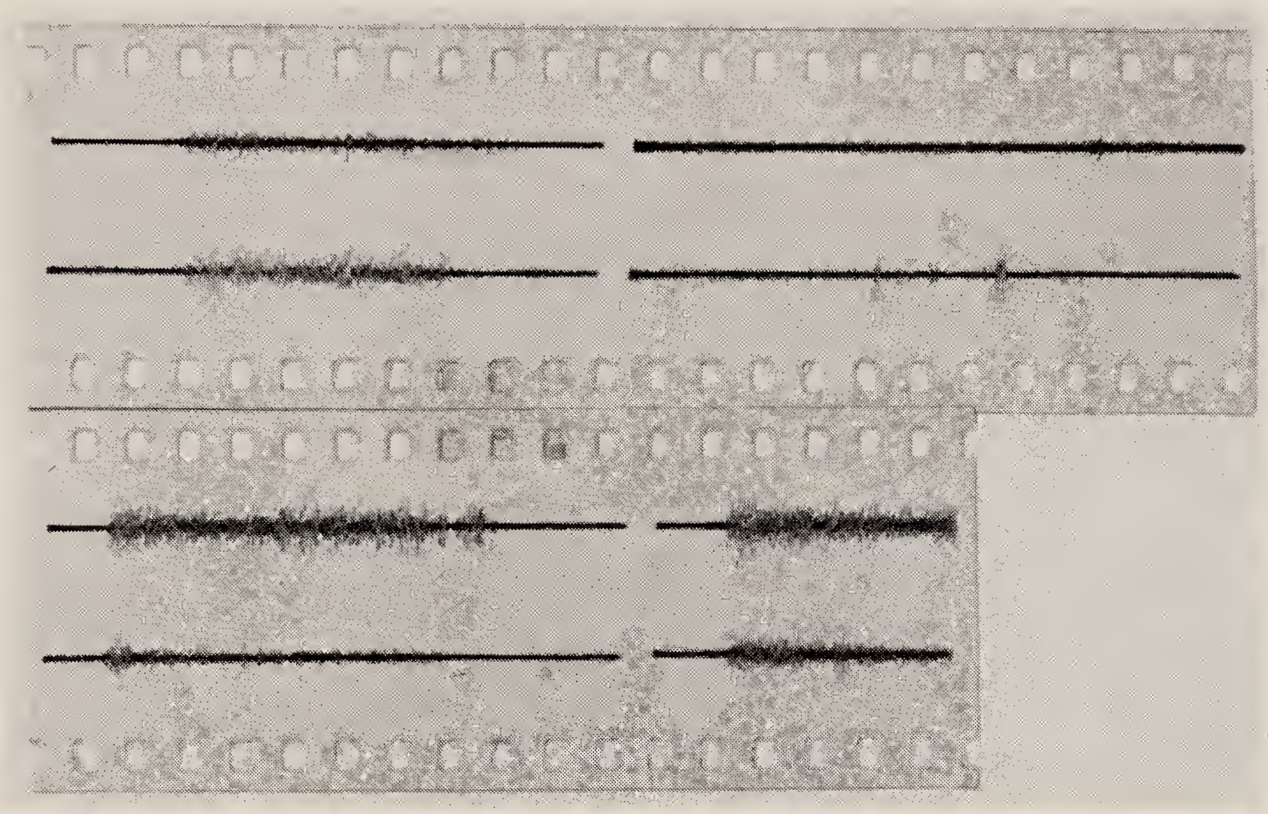


Fig. 4.—Electromyograms of the upper and lower lips showing the electrical activity with lips apart, then with lips held together, and finally relaxed again. Twin S. shows greater electrical activity of her lower lip.

Fig. 5.—Electromyograms of the masseter muscles at rest, showing reduced activity in twin L. because of the forward posture. Twin S. shows more electrical activity in her right than in her left masseter.

DISCUSSION

The aetiological factors may be considered as:—

1. The developmental position of $\underline{1|1}$ in the maxilla.

2. The differing relative eruption times of $\overline{1|1}$ and any adaptive behaviour this may cause.

3. The timing of the loss of all four 6's and the effect on the positions of the incisors and on the behaviour of the lips.

The first reason should be logically dismissed unless more evidence comes to light. The developmental positions of $\underline{1|1}$ should be the same in both identical twins, barring an accident for which there is no evidence.

The second reason deserves more credence as the evidence shows the twin with the increased overjet is slightly heavier and taller (she was the heavier baby at birth) and she has a constant history of her teeth erupting ahead of her sister by 3 to 6 months. Hence the logical conjecture must be that in the 3 months between the eruption of $\underline{1|1}$ in twin S. and the eruption of $\underline{1|1}$ in twin L., one of them began to establish a reflex pattern of oral seal which had not been necessary or had not mattered with the deciduous incisors. Ballard (1962) postulates that the reason for lip sealing is due to 'an inherent physiological tendency to maintain an oral seal' and that this probably becomes 'a reflexly established posture'. Hence, in twin L. with the more normal overjet there is an established reflex to keep the anterior oral seal. This includes a forward posturing of the mandible in speech and at rest, and a lip seal effected by circumoral contraction. Ballard also stated that the alternative way to establish an anterior oral seal is by pushing the tongue forward to contact the lower lip and thus together contact the palatal side of the upper incisor teeth.

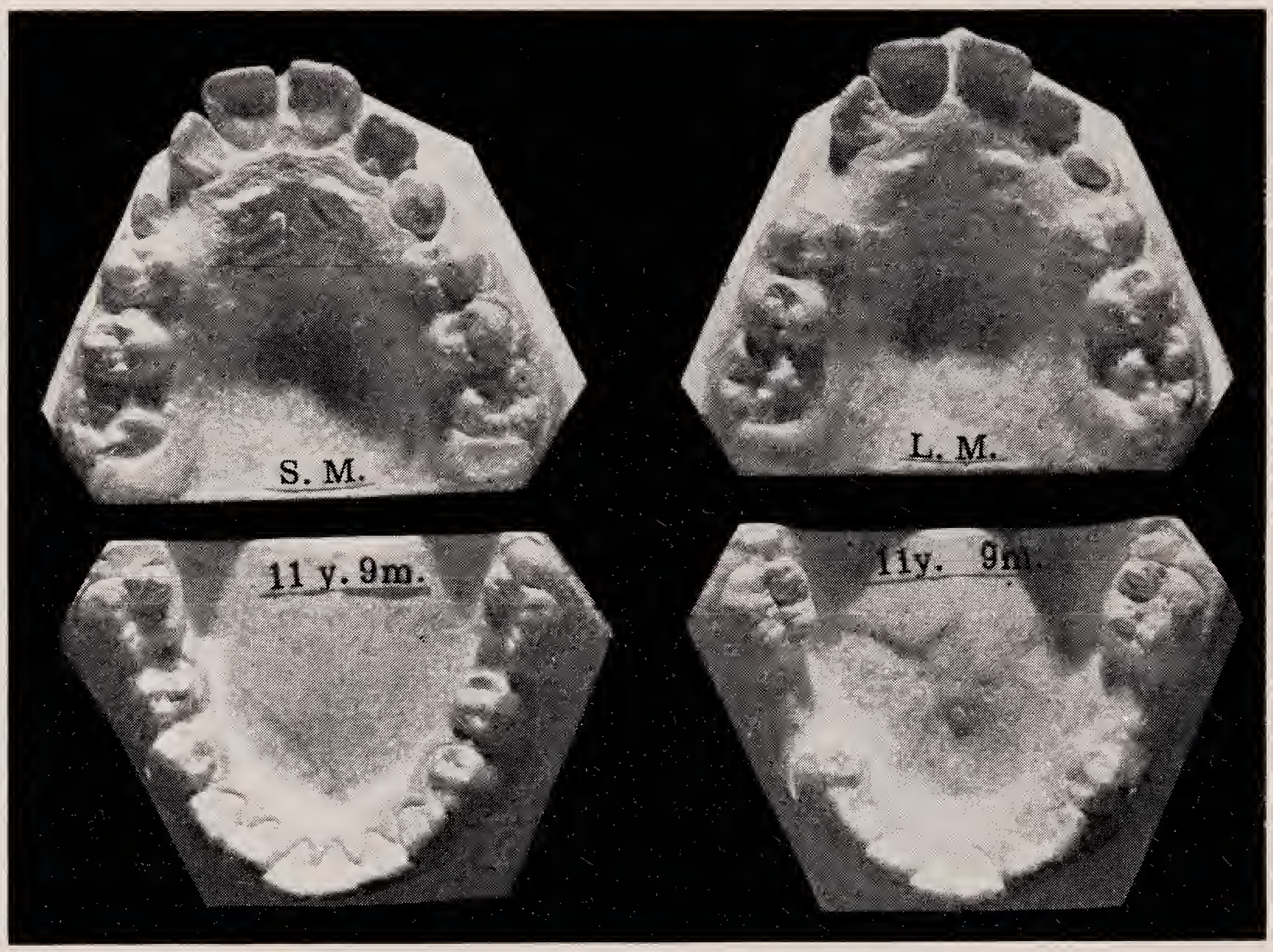


Fig. 6.—Occlusal view of the twins' models showing the eruption of $\underline{3|}$ and $\overline{5|5}$ to be ahead in twin S. and also indicating the similar tooth morphology.

In twin S. the latter method of oral seal has been adopted, and this is the form of oral seal most frequently found in Class II, division 1 malocclusions.

In trying to account for the difference, the mother recalled that twin S.'s two central incisors did erupt first and that she was slightly ridiculed as the twin with the two big front teeth. This was at 7 years of age, when her sister still had deciduous incisors.

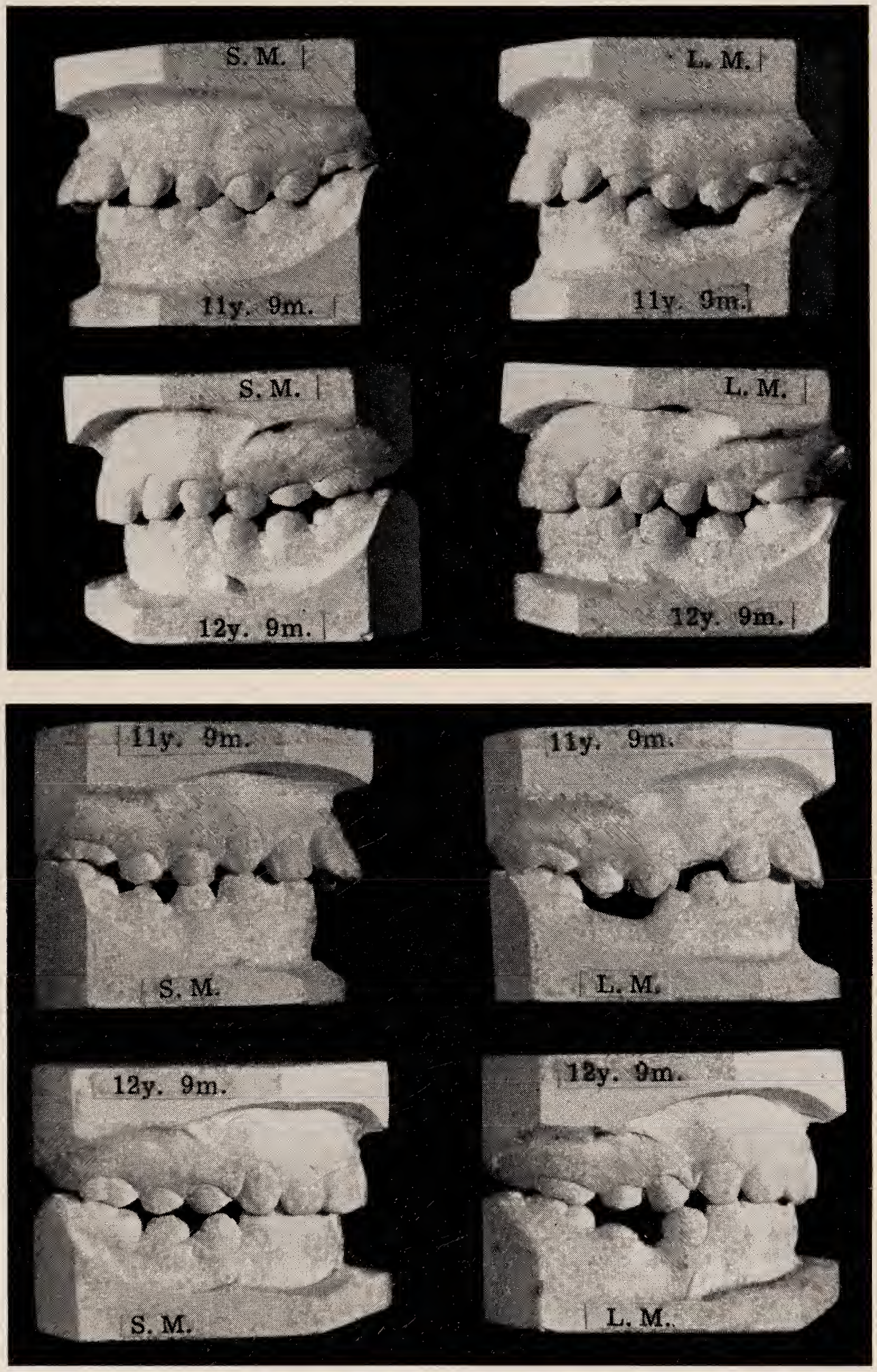


Fig. 7.—Lateral views showing the difference in overjet between twin S. and twin L. and the appearance after one year of treatment.

Hence it was that twin L., hearing this ridicule of her sister, must have made up her mind that no one whould criticize her. Her mother says that she used to hold her lower lip in front of her upper incisors continually, to hide them from view. This latter would suggest the habit nature of the oral-seal pattern in twin L. as compared with twin S.

The third postulation might be a contributory cause in that the loss of $\overline{6|6}$ at 8 years of age encouraged more retroclination of the lower incisors in the face of the lower-lip contraction. This caused the difference in overjet to be increased slightly due to lower incisor retroclination, but I feel that the main differences are due to the habitual behaviour adaptations.

CONCLUSIONS

As Leech (1955) pointed out in his paper, it is unwise to attempt to prove or disprove established concepts with single cases. What I have tried to do is to present these cases in the light of the present theories of lip and mandible posture. The paper was illustrated by cine-film and cine-radiography.

Acknowledgements.—I would like to thank Mr. R. E. Rix and Mr. K. E. Pringle for their helpful comments and views about these cases and for permission to publish these cases; Dr. W. J. Tulley for his electromyograms and for his criticism, help, and interest at all stages of the preparation of this paper; Dr. A. Grant for the blood serology; Chief Superintendent J. Godsell, of Scotland Yard, for the finger-prints; Mr. B. A. Jones of the Dental Photographic Department, Guy's Hospital, for the photography; and Mrs. Y. Rawlins for the tracings and clerical assistance.

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DISCUSSION

The Chairman (Mr. S. G. McCallin) said that they were all interested in twin cases. One thing that Mr. Benzies had not mentioned was that everyone knew how critical the extent of an overjet could be in causing a patient to adopt mandibular postures, and it might be that, in this case, twin L., who was the one who did the posturing, had a dental-base relationship which was very slightly less Class II than twin S. The tracings which Mr. Benzies had shown did not suggest this, but tracings were subject to many errors.

Mr. C. P. Adams said that it seemed to him that in the full-face photograph the twin S. had a facial asymmetry; one eye seemed to be a little lower than the other. In the circumstances, it seemed a pity that postero-anterior headfilms had not been compared. Did Mr. Benzies think that there was a facial asymmetry in this twin, and would the examination of postero-anterior headfilms clarify the matter?

Mr. W. A. Nicol criticized one point; when Mr. Benzies was presenting the cephalometric radiographs, he mentioned a difference in angle of 1°. In a paper earlier in the year by Mr. Broadway, he had pointed out very effectively that there could be very considerable experimental errors in cephalometric radiographs. Had Mr. Benzies taken that into account?

Mr. S. Haynes congratulated Mr. Benzies on his beautiful radiographs of the soft and hard tissues, and asked if further details of the technique could be given.

He also wished to query the suggestion that extraction of lower 6's in one twin had permitted retroclination of lower incisors to occur. The difference was so small that it could be accounted for by tracing error.

It was difficult to discuss the soft tissues since their appearance at rest was not shown in the cases presented, but he would like to know if they were alike or different when in the resting position.

Mr. C. P. Briggs said that Mr. Benzies had shown an electromyograph of the circumoral muscles of both twins, and asked if he had done any investigations of the temporal muscles to show the forward postural movement of the twin who postured forward?

The degree of lower incisor retroclination in one twin was far less than in the other child. He got the impression that it was where the child had had her molar teeth removed at a favourable date.

Mr. H. E. Wilson said he had thought, like Mr. Adams, that there was a degree of asymmetry. On one twin, the left masseter was stronger than the right, and on the other the right masseter was stronger than the left. That could be explained in one of two ways: either there

was a cross-bite of some sort which could produce over-activity on one side, or there was some degree of asymmetry which showed up again as an over-activity of one muscle.

The Chairman wondered whether the differing responses were in any way related to the time of extraction of the first molars when there was some drift to one side or the other. Was there possibly some displacement activity at work, and was the patient taking some kind of avoiding action to overcome the displacement?

Mr. C. D. Parker asked if there had been any electromyograph recording of the lower lip during expressive behaviour, because he thought that possibly some of the difference in the overjet might, in fact, be due to that.

Mr. Benzies, in reply, thanked Mr. McCallin for his remarks. With regard to the dental base being slightly less in twin L. than twin S., he felt that 1° was inconclusive.

He agreed with Mr. Adams that the asymmetry on one side was more marked in twin S. than in twin L., but there was an asymmetry of both twins, and it was on the same side.

To Mr. Nicol, he said that both he and Mrs. Rawlins had taken recordings. The average had come out to about 1°. They got a frightening lot of variations. He never got twin L. to look more Class II than twin S.

In reply to Mr. Haynes, he said that, with the cephalometric X-rays, a triangle-shaped aluminium inset was used, which brought out the soft tissue. The lower incisors were retroclined in twin S. and the difference between the two was about 1½°.

Mr. Haynes said that one would not accept a difference of 1° if basal relationship was being made.

Mr. Benzies replied that 1° was not very much on a tracing, the differences were very slight and were difficult to draw and measure. Clinically it had come out to a 3-mm. difference, and a 7-mm. overjet for twin S. and a 4-mm. overjet for twin L. It still came within Lundstrom's outside limits for monovular twin.

THE INDIRECT CONSTRUCTION OF ORTHODONTIC APPLIANCES

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Edinburgh Dental Hospital and School

THE technique to be described is based on that of Lindquist (1959a, b). For convenience of description it can be divided into two sections: (1) Chairside Procedures, and (2) Laboratory Procedures.

1. CHAIRSIDE PROCEDURES

At the first visit impressions for record casts are taken, if this has not already been done. The record casts are used to make special trays as described under laboratory procedures below. The placing of separators between the contact points of the teeth to be banded is the other procedure carried out at this stage. Separation of the teeth to be banded is essential. Brass ligatures or elastic thread are used for the separation of the posterior teeth. The anterior teeth are separated by the use of Maxian elastic separating strips (*Fig.* 1). The patient is instructed in their use and given a supply with instructions to place them the day before the next visit.

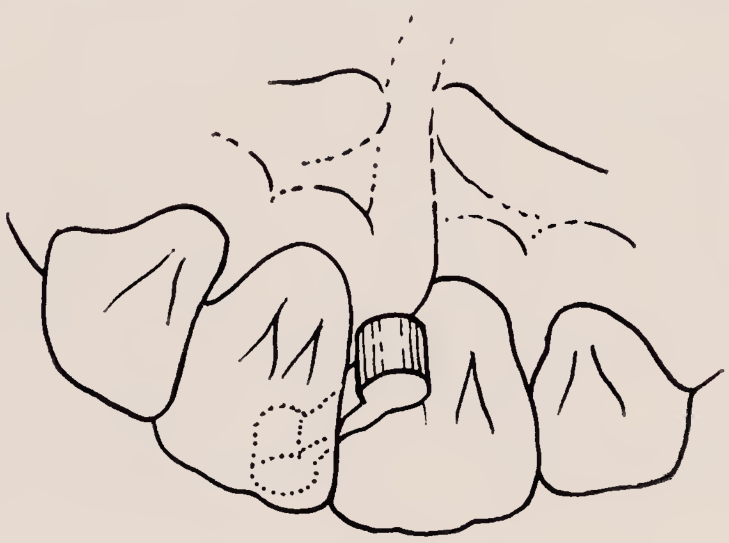

Fig. 1.—Anterior teeth with Maxian elastic separator in position.

The second visit is timed a few days after the first. The separators are removed, and all teeth to be banded are given a thorough clean and scaled if necessary. Where it is desired to retract the gum tissues, as from the distal surface of a recently erupted molar, a piece of string or a wisp of cotton-wool soaked in 20 per cent zinc chloride solution is packed between the gum and the tooth surface at the beginning of the appointment, and the tissue will be retracted by the time one is ready to take the impression. A heavy-bodied rubber-base impression is then taken in the special tray. A firm pressure should be maintained to drive the impression material into the gingival crevices and between the contact points. A successful impression should show a septum of rubber between the separated teeth and a feather edge round the gingival margins. After the impression has been taken, separators are again placed between the posterior teeth and the patient is instructed to place the anterior separators as before on the day preceding the third visit, when the appliance, which has been constructed in the laboratory as described below, is cemented in place.

2. LABORATORY PROCEDURES

a. **Construction of the Special Tray.**—A special tray is made on the record cast, which has been French chalked and covered with one thickness of base-plate wax. The special trays are made of Kemdent or other suitable tray material.

b. **Casting the Impression.**—The rubber-base impression is boxed in with ribbon wax to a height of about 5 mm. The working model is cast in plastic steel (80 per cent steel filings, 20 per cent plastic). This is obtainable from ironmongers, tool shops, and elsewhere, and makes an accurate die with good surface hardness. The material is mixed according to the maker's instructions. To avoid air-bubbles the material may be painted on to the tooth surfaces first. One box of plastic steel is

Based on a demonstration given at the Edinburgh meeting held on 12 May, 1962.

sufficient for one model. *Fig.* 2 shows the required depth of model beyond the impression of the tooth crowns. The model is left overnight to set and then removed from the impression and the sides trimmed with a slight taper towards the base.

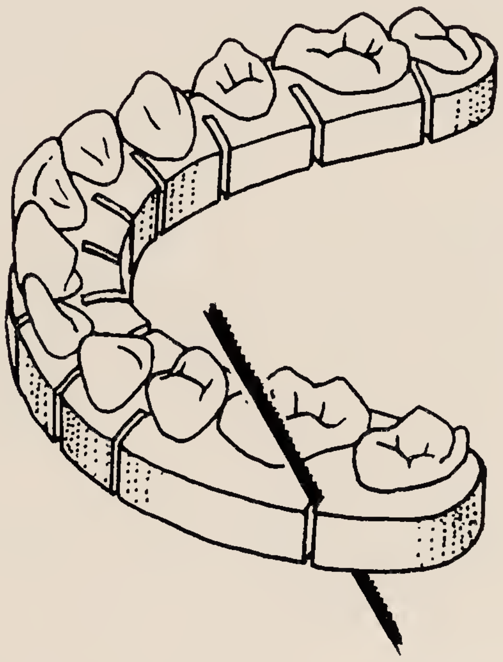

Fig. 2.—Plastic-steel model after trimming, showing cuts in base with fine fret-saw. Note contact points not cut through at this stage.

c. **Fashioning the Individual Tooth Dies.**—A cut is made with a disk or fret-saw between each tooth from the base to within 2 mm. of the contact area (*Fig.* 2). A hole is then drilled in the centre of the under surface of each tooth and a dowel pin, as used for crown and bridgework, is fixed in place with the cold cure acrylic (*Fig.* 3). The plastic-steel model, with the dowel pins in place, is then embedded in a base of stone plaster up to about two-thirds of the depth of the walls of its base. The base of the plaster box so formed is then lightly trimmed to expose the free ends of the dowel pins. This exposure of the dowel pins facilitates the removal of individual teeth from the plaster box for banding. The model is then removed from the box and the cuts between the teeth completed. Each tooth can now be removed for band construction and replaced exactly in its position in the arch (*Fig.* 4).

d. **Band Making.**—The tooth die is removed from the box and held in a suitable vice by the dowel pin. The bands are made, using the technique of choice, and the tooth replaced in the box. Before making bands for posterior teeth, the tooth die must be trimmed, cutting away the gingival margin following the tooth contour to a depth of 2–3 mm. (*Fig.* 4). This is the crucial step in the laboratory procedures, and the one where teething troubles are most likely. A good technician will soon acquire the feel for tooth form; a study of natural teeth is a considerable help in this respect.

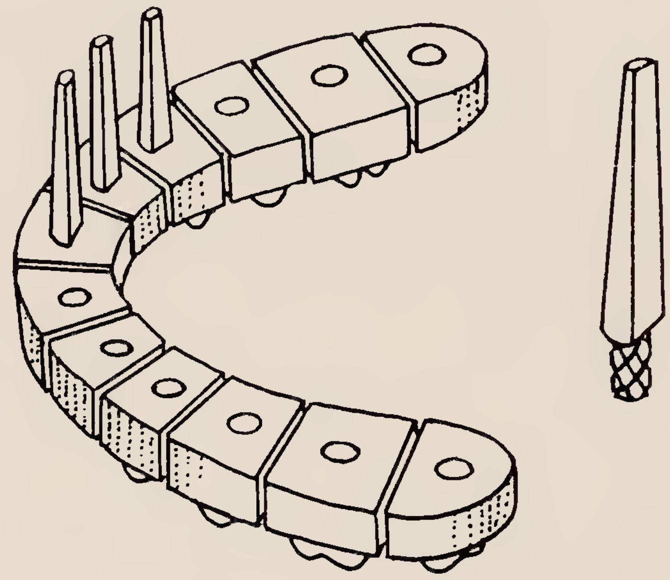

Fig. 3.—Underside of model showing holes for dowel pins and pins in situ.

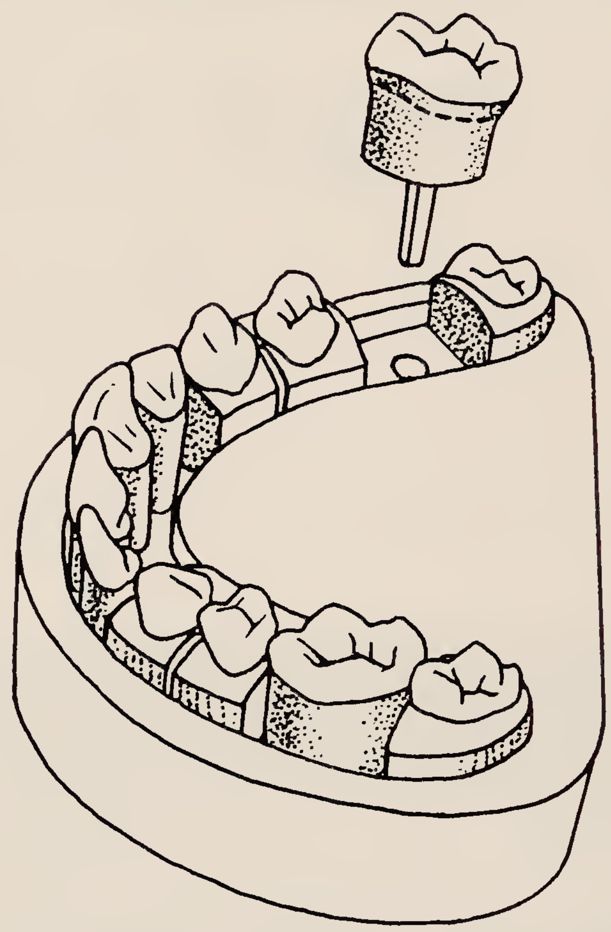

Fig. 4.—Model in plastic box, cuts completed, segments trimmed to make individual dies of teeth to be banded. Broken line $\lfloor 6$ extent of trimming at gingival margin (*see text*).

e. **Placing Buccal Tubes, Lingual Arches, etc.**—A technician who is accustomed to welding tubes and arches on to a band set in a plaster cast with a 'cut away' for access for welding may experience a little difficulty at first working free-hand. To place buccal tubes,

take a length of tubing, and, holding it in position, score the band horizontally above and below the tubing and with vertical marks delineate the area of attachment. Then remove the band and tack-weld the tubing to the band, replace and check the alinement, adjust as necessary, complete the weld or weld and solder according to practice, and then, with a disk, cut off the excess lengths of tubing mesially and distally.

ADVANTAGES AND DISADVANTAGES

Experience to date with a limited number of cases indicates that where molar bands only are to be made there is no great saving in chairside time and some increase in laboratory time and expense. When anterior bands are to be made as well, chairside time and energy are saved.

From the patient's viewpoint there is much less discomfort and fatigue. This is an especial advantage with younger patients.

The fit of the bands is as good if not better than those made directly, once the technique is mastered.

Acknowledgements.—We would like to express our thanks to Miss M. Benstead, Medical Illustrator, Edinburgh Dental School, for her care and skill in preparing the illustrations.

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THE CARE OF THE PERIODONTAL TISSUES DURING ORTHODONTIC TREATMENT

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A GREAT deal of consideration has been given to the techniques of orthodontic therapy, but one aspect which has received little attention is the care of the periodontal tissues during treatment. The need for such care became apparent during a survey just recently completed by the authors. In this, the patients who were examined had received orthodontic treatment some years previously. Some of the mouths examined in the review showed considerable neglect and active periodontal disease. Two examples are seen in *Fig.* 1.

A

B

Fig. 1.—A, Clinical appearance of patient A, 3 years after completion of orthodontic treatment. B, Appearance of patient B, 5 years after completion of orthodontic treatment.

Demonstration given at the Edinburgh meeting held on 12 May, 1962.

As may be observed, the end-result in both patients, from an orthodontic point of view, is satisfactory. However, examination of the supporting tissues shows chronic gingivitis and periodontitis associated with poor oral hygiene.

It is not suggested that orthodontic treatment has caused the conditions illustrated. It is suggested, however, that before starting orthodontic treatment more attention should be paid to assessing the health of the periodontium as well as the caries experience. The orthodontist generally ceases to see his patients after the age of 15–16 years, and at the time of discharge the patient should be sufficiently inculcated with the knowledge of, and necessity for, good oral hygiene.

The regular visits normally required for orthodontic treatment provide the clinician with an excellent opportunity to establish and encourage good habits of oral hygiene. While opinion may be divided concerning the merits of toothbrushing in the control of caries there is no doubt as to its effectiveness in maintaining the health of the periodontium (W.H.O. Report, 1961).

GENERAL MEASURES OF CARE

It is desirable that a patient whose mouth is neglected and who presents for orthodontic diagnosis should be told that treatment will not be undertaken unless there is a considerable improvement in the standard of oral hygiene. The parents should be informed as to what is required, and after instruction has been given in the care of the mouth the patient should be dismissed and reviewed in 3 months. Such an observation period is adequate to assess the degree of patient co-operation. Furthermore, when treatment has started, it should be emphasized that any failure to maintain a reasonable level of care will jeopardize the continuation of orthodontic treatment.

A discussion on oral hygiene methods is not sufficient. Instead, careful practical instruction must be given, preferably with models and a toothbrush. The specific technique of toothbrushing is a matter for individual preference, but where fixed appliances are in place certain modifications are necessary and these are discussed later.

There is some evidence that the movement of teeth with orthodontic appliances can cause gingivitis (Skillen, 1940; Spence, 1955). This may be a transient condition, but where there is a susceptibility to gingival inflammation and this is aggravated by orthodontic appliances, the resultant hyperplastic gingivitis may not resolve. When this happens the tissues become oedematous and tend to produce a non-functional form in relation to the adjoining teeth. This, in turn, creates a retention area for food debris in which bacteria proliferate and cause crevicular ulceration and bleeding. A vicious circle is thus established with a gingivitis progressing to periodontitis.

SPECIFIC MEASURES OF CARE

Removable Appliances.—The length of time per day during which an appliance should be worn is a matter of controversy. Most orthodontists recommend continuous wear during active treatment because they feel that patients are less likely to fail to wear their appliances and that a more rapid tooth movement is thus achieved. The work of Reitan (1957) casts doubt on this last viewpoint, but there are situations where the full-time wearing of an appliance is desirable. Examples of this are the correction of instanding incisors with a reverse overjet and deep overbite, retraction of upper incisors where there is marked contraction of the lower lip behind them, and the correction of a unilateral posterior cross-bite.

There are, however, many phases of treatment in which a satisfactory tooth movement is obtained by the wearing of an appliance intermittently, preferably not less than 12 hours per day. It would appear in these cases that the periodontal tissues are maintained in a better state of health.

It is desirable to minimize appliance movement in the mouth, especially if the appliance is being worn full-time. *Fig.* 2 shows a localized hyperplastic gingivitis, partly due to the movement of the appliance, and this could have been avoided by the addition of a labial bow.

In tooth movement a free-ended spring may cause considerable damage if it is placed too near the gingival margin of a tooth. Palatal springs should not be allowed to press against the soft tissues, since this tends to produce an inflammatory reaction.

Fig. 2.—Appliance of poor design predisposing to gingivitis.

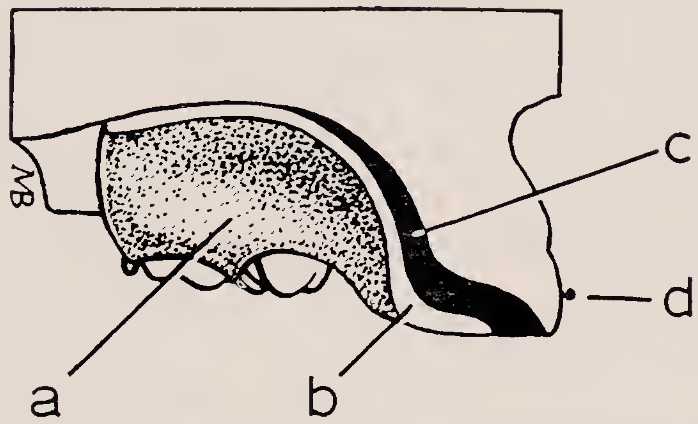

Fig. 4.—Cross-section of a maxillary model with appliance in situ. The appliance has been trimmed to permit palatal movement of the maxillary anterior teeth. a, Appliance, b, Cross-section of appliance, c, Space left after appliance trimming, d, Cross-section of labial bow.

The trimming of an appliance demands care. A common site of gingival inflammation is the palatal tissue behind the maxillary incisors when these are being retracted. *Fig.* 3 shows this type of reaction, which can be avoided by trimming the bite-plane as illustrated in *Fig.* 4.

Fixed Appliances.—Waerhaug (1957) has shown how well the gingival tissues will adapt to a metal ligature placed tightly round the tooth immediately above the cemento-enamel junction. Applying his findings to orthodontic bands on the posterior teeth, several clinical points in technique arise. Scaling and polishing of teeth should be carried out to remove any calculus or plaque prior to the cementing of bands. The gingival edge of the band should be smoothed and polished, and the band extended into the gingival crevice. This reduces thc tendency for food retention and plaque formation which Waerhaug has shown to be the important factors in preventing the satisfactory adaptation of the gingival tissues to a metal surface, thus maintaining a healthy gingival cuff during treatment.

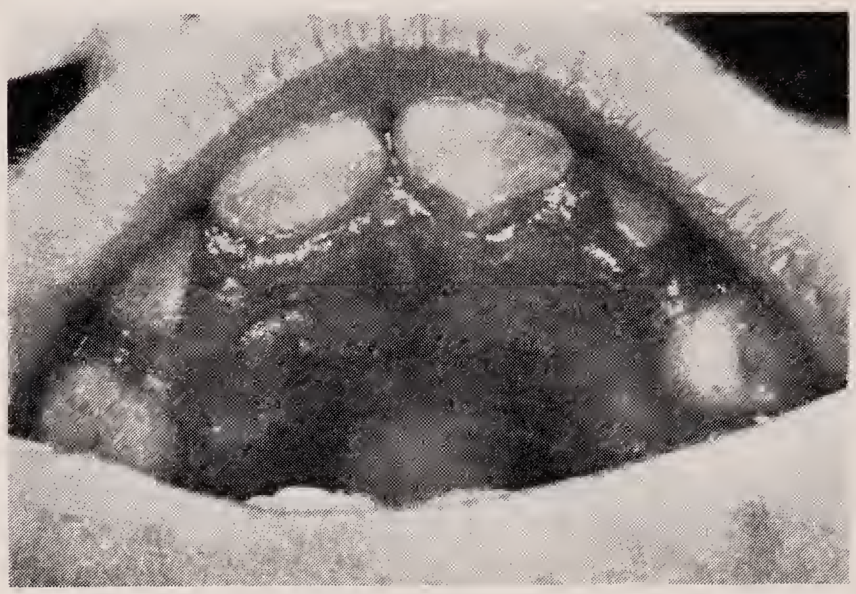

Fig. 3.—Hyperplastic gingivitis around maxillary anterior teeth caused by orthodontic appliance.

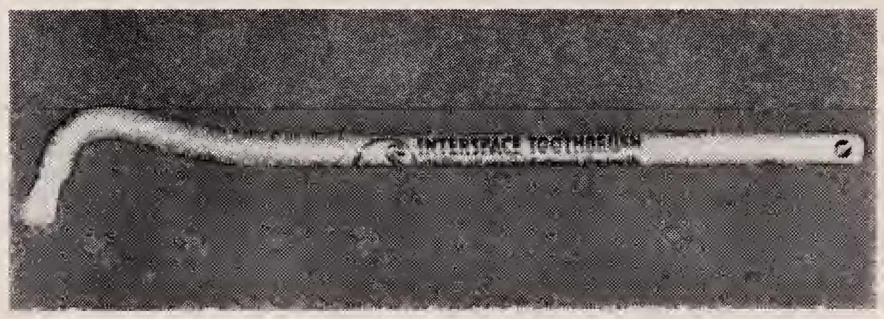

Fig. 5.—Interspace brush suitable for cleaning around fixed appliances.

On removal of the bands, scaling of the teeth and polishing with soft rubber cups to remove cement, calculus, and plaque will ensure the healthy readaptation of the gingivae after treatment.

Oral Hygiene.—In toothbrushing a horizontal technique of the Charter's type appears to be the most satisfactory. Where removable appliances are worn, care must be given to the area covered by the appliance and when possible the appliance should be cleaned after meals. Where fixed appliances are used, an interspace brush (*Fig.* 5) has been found the most efficient means of cleaning since it has a single tuft of bristles which can be easily

carried into the stagnation areas created by the ligatures, brackets, and wires. Furthermore, the use of a different brush serves to remind the patient that additional care of the mouth is required when fixed appliances are present.

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APPLIANCE TREATMENT OF UNERUPTED MAXILLARY CANINES

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Canines commonly impact palatally. This happens more rarely high up in the line of the arch due to insufficient room for the canine or local pathology.

Where the canine is impacted palatally in a teenager and it is decided during the diagnosis that the canine can be brought into the line of the arch (Bird, 1960; Hartley, 1956; Hitchin, 1956; Kettle, 1958; McKay, 1961), then it is advisable to expose the canine as soon as possible.

A palatally impacted canine may take years to break through the mucous membrane of the palate or may fail to erupt at all. Early exposure confirms the position of the canine clinically and assures that its morphology is normal; if other orthodontic treatment is necessary, for example, to create room in the arch for the canine, then eruption into the mouth can proceed during this preliminary orthodontic treatment.

Fig. 1.—An upper left canine has been brought from the palate into the line of the arch by means of an elastic band guided from the hook on the canine band by means of a lateral arm on the removable appliance.

The appliances used to move the palatally impacted canine into position may be removable or fixed, or a combination of a removable appliance with a fixed attachment on the canine.

Very often the canine is so poorly placed, or insufficiently erupted, as to make the fitting of a removable appliance impracticable, and even when the canine is in a favourable position the

Demonstration given at the Edinburgh meeting held on 12 May, 1962.

spring may ride up the sloping palatal surface or may be difficult for the patient to insert. A fixed appliance is difficult to adjust and usually it is necessary to fit a removable appliance at some stage during treatment with bite-blocks on to allow the canine to clear the lower occlusion.

Fig. 2.—A silver cap and hook cemented on the palatally displaced upper canine with an elastic band applying lateral traction.

The combination of fixed-removable appliance designed to move the impacted canine into the line of the arch consists of a hook fixed to the canine from which an elastic band is guided buccally by means of a lateral arm soldered to the crib of the removable appliance. Distally, the elastic is hooked to a small extension of the lateral arm (*Figs.* 1, 2). The same principle of a lateral arm guiding an elastic band can be applied to other palatally or lingually displaced upper or lower teeth. When the canine has been brought by elastic traction from its position in the palate almost into the arch line, the elastic can be discontinued and the lateral arm applied directly to the hook to bring the canine into its final position.

There are three methods of attaching the hook to the canine. The canine may be banded with the hook attached to the band; this is the method of choice. It is often impracticable to band the canine, owing to its position or degree of eruption in the palate. A hook can then be attached by means of a small hole drilled through the distal slope of the canine ridge or by means of a pin sunk into the canine. This method is to be avoided, as it may lead to caries and the hook may rotate or come out. A very satisfactory alternative is to cast a silver cap with a hook, which is cemented by means of Ames Black Copper cement to the canine (*Fig.* 2). It is quite remarkable how well a cemented silver cap stays on a small area of the canine surface.

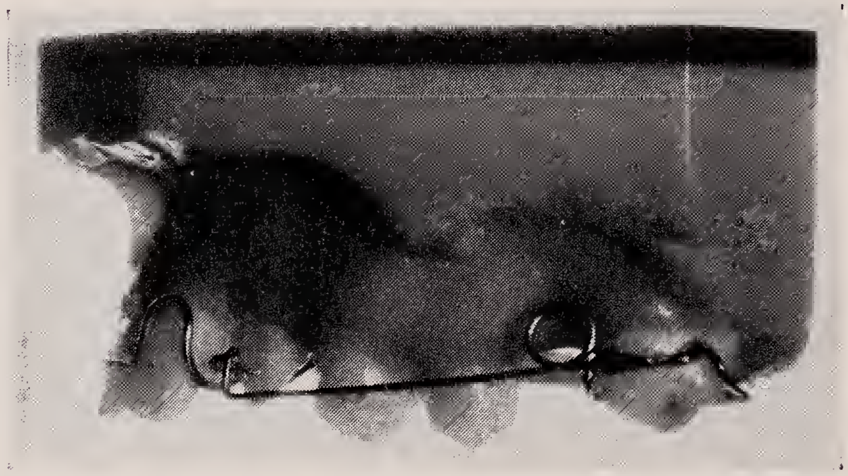

Fig. 3.—A canine being brought into position from high up in the arch in a 22-year-old patient. The method used here of fitting the hook to a small hole drilled in the canine is not recommended; a silver cap is far more satisfactory.

It is usually sufficient in the case of a canine impacted in the line of the arch to create sufficient room and it will then erupt; no appliance treatment is necessary.

In certain cases, as in the case of the older patient, if deeply placed it may be considered advisable to accelerate the delayed eruption and also guide the canine into position. The appliance also preserves the space for the canine. Where active appliance treatment is considered necessary, the appliance used has a lateral arm with a simple loop in it passing directly to a hook in the canine (*Fig.* 3).

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OBSERVATIONS ON SUBMERGING DECIDUOUS MOLARS

THE FIRST CHAPMAN PRIZE ESSAY

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A SUBMERGING tooth can be defined as one which fails to maintain its position in the developing occlusion, and may become partially or completely re-enclosed in the oral tissues. This term 'submerged' is objected to by Vorhies, Gregory, and McDonald (1952) on the grounds that the tooth is enveloped in growing tissues and does not sink into them. Other terms have been suggested, such as 'suppressed', 'depressed', 'retained', and 're-enclosed', the latter being perhaps the best choice. However, the term 'submerged' is generally used and gives a description of the clinical appearance, and is best adhered to until all the facts relevant to the condition are determined.

The appearance of a severe form of this condition is shown in *Fig.* 1. From this radiograph it might appear that the lower second deciduous molar had never erupted. However, the progressive nature of the condition is now well known, following the pioneer study of Chapman (1937) using serial dental casts. In the clinical practice of orthodontics these submerging deciduous molars are not infrequently encountered, and can provide a difficult problem in treatment planning.

The current explanation of the failure of these teeth to maintain their occlusal height is that an ankylosis or union between bone and tooth is present. The original observation of ankylosis by histological methods was made by Noyes (1932). However, Skillen and Walley (1937) consider that this is not an invariable finding, but further histological evidence to support the concept of ankylosis has been produced by Vorhies and others (1952).

Suggestions have been made that trauma or the effects of a previous illness may be predisposing factors. Noyes (1932) considered the possibility of rickets, but found that the histological appearance did not support this hypothesis. Mechanical trauma as a causative agent has been disproved by Biederman (1956),

Fig. 1.—Submerged $\overline{\text{E}|}$. $\overline{5|}$ has erupted distally after extraction of $\overline{6|}$.

and in a later publication (1962) he suggests a local disturbance of metabolism as a possible factor.

A number of cases have been reported in which several members of the same family have shown the condition, and Capon (1944) described 2 such examples in brothers. Further, Ballard (1940) reported 2 cases and Visick (1944) 1, with a family history of the condition, and lastly Johnson (1944) described submerging deciduous molars in identical twins.

A further possibility advanced by Capon (1944) and Glucksman (1942) is that a localized failure or disturbance of alveolar bone growth has occurred. The tendency of submerging deciduous molars to occur in groups and in combination, occasionally with failure of the succeeding premolars to reach full occlusion, is given as supporting evidence.

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Given at the meeting held on 8 October, 1962.

Local factors, such as impaction between adjoining teeth, have been stated to be a precipitating factor in some cases by Izzard and Dorian (1929), but against this is the evidence of Capon (1944) that this phenomenon may occur even when the teeth are spaced. Tulley (1950) reported a case of submerged deciduous molar impacted against a denticle, and occasionally it has been suggested that the effects of tongue pressure, apical infection, or even cystic pressure, may precipitate the condition. Finally, it is interesting historically that this anomaly has been reported by Schott and Zuhrt (1958) in a skull found in Leipzig dating from the German peasant wars, and it has also been observed in an Anglo-Saxon skull.

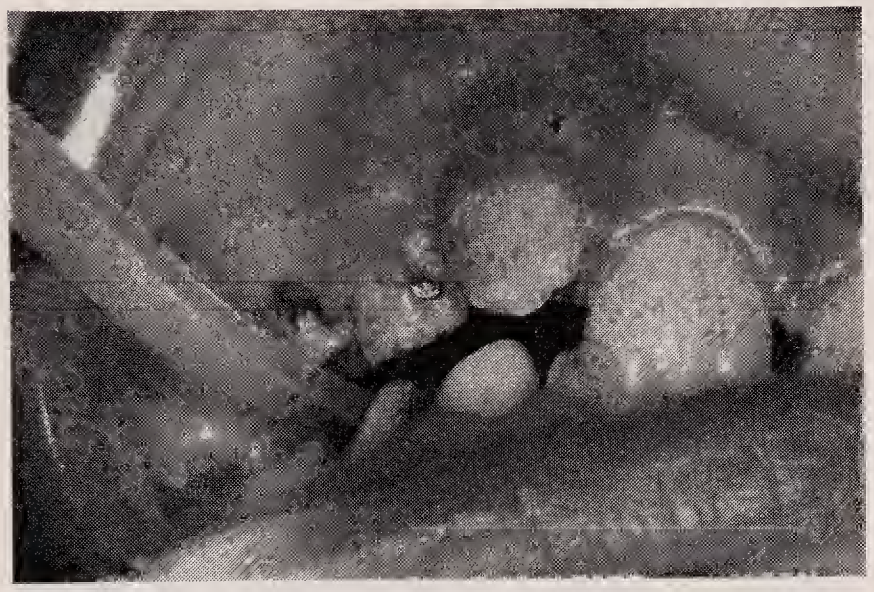

Fig. 2.—Method of assessing infra-occlusion of deciduous molars.

Following this review of the literature it may be said that many aspects of this anomaly are as yet not fully understood. It was therefore decided firstly to undertake an investigation of the incidence of the condition, as little information is available on this, and indeed submerging molars are usually considered to be rarities and individual case reports are often presented on this assumption.

INCIDENCE AND DISTRIBUTION

Minor degrees of this abnormality are frequently overlooked, for if the teeth are examined with the mouth wide open nothing unusual may be noticed. Only a close examination of the teeth in centric occlusion will reveal a minor vertical abnormality of the deciduous molars. Even a large degree of the abnormality is easily overlooked, and if not is referred to as a lateral open bite. This impression of a lateral open bite is strengthened, as the first permanent molars may also, in some cases, be out of occlusion, and may also become deeply placed and impacted, giving a similar appearance to a submerged deciduous molar. It has been reported that impaction against the adjacent second deciduous molar is one cause of this anomaly in the permanent dentition (Dixon, 1959), but as this could not apply to the eruption of the deciduous molars, impacted permanent molar teeth are excluded from this study; but of course this does not infer that other factors are not common to both conditions.

To establish the incidence of submerging deciduous molars 400 children from a primary school were inspected for the presence of the condition. In this example, 10 children were discovered to have one or more submerging deciduous molars. Therefore in this sample 2·5 per cent of the children showed the condition on a single inspection. It appears, therefore, that this abnormality is far more frequent than usually suspected.

As a source of further material, an examination was made of the study casts of 200 children at the stage of the deciduous and mixed dentitions. These were taken from patients attending for observation or treatment of malocclusion. In both groups a submerging deciduous molar was recorded if the tooth was 1 mm. or more in infra-occlusion. The method of assessing this by the use of a 1-mm. thick rubber strip is shown in *Fig.* 2. This method could be applied to both a clinical examination and an examination of dental casts, and if the rubber strip could be withdrawn between the teeth in centric occlusion a condition of infra-occlusion was recorded.

Using this method it was noted that in the second group one or more submerging deciduous molars were present in 21 cases. A statistical analysis may be made of the relative incidence of submerging deciduous molars in the two groups investigated. The use of the usually accepted statistical tests (Hill, 1950) was possible, as the groups of children were similar in age distribution (5–10 yr.).

The S.E. of the difference between the two proportions

$$=\sqrt{\left(\frac{p1\times q1}{N1}+\frac{p2\times q2}{N2}\right)}$$

$$\simeq 2{\cdot}5 \text{ when } \begin{matrix}(p1=2{\cdot}5,\ q1=97{\cdot}5)\\(p2=10{\cdot}5,\ q2=89{\cdot}5)\end{matrix}$$

Therefore, the incidence of submerging deciduous molars was significantly higher at the 1 per cent level in the group of orthodontic patients than in the group of unselected schoolchildren examined. In both groups the 31 cases observed had 83 submerging deciduous molars distributed as indicated in *Table I*.

Table I.—Distribution of Submerging Deciduous Molars

Individual Teeth	Right Side	Left Side
Upper second deciduous molar	7	4
Upper first deciduous molar	10	7
Lower second deciduous molar	18	11
Lower first deciduous molar	13	13
Totals	48	35

The lower arch was affected more than the upper, and in many cases the lower first deciduous molar was the first to show the condition, but this was not invariable. All the teeth were affected to some degree, and on both sides of the mouth the incidence of involvement of the teeth varied as the ages of the patients increased, and the older patients had a higher incidence of submerging second deciduous molars.

Bilateral instances were found in 18 out of the 31 cases. Unfortunately, radiographs were not available for all of these patients, but 2 patients had a congenital absence of lower second premolars with submerging lower second deciduous molars.

The arch relationship was investigated in the group of dental casts: 12 cases were of Angle's Class I malocclusion, 5 of Angle's Class II, division 1; 2 of Angle's Class II, division 2; and 2 of Angle's Class III. Thus the condition cannot be directly related to the arch relationship. There were, however, 3 cases of anterior open bite of varying degree, and one instance of a marked posterior lateral open bite with the incisors being the only teeth in occlusion.

In this series few of the involved teeth appeared carious, and none abscessed. The patients gave no relevant history of illness or trauma, although in one instance enamel hypoplasia of the teeth was present.

Summarizing the most important points shown by this analysis so far, it is seen that the condition is frequently bilateral and usually involves more than one tooth in each dentition, therefore a local cause for the condition is unlikely to be the only factor involved. Secondly, that submerging deciduous molars are more frequent than hitherto suspected and any aetiological factor must be of fairly common occurrence. Finally, they are more common in children with a malocclusion, but no single type of malocclusion can be implicated.

CLINICAL OBSERVATIONS

The second group of observations made were based on the clinical appearances seen in orthodontic patients. In the practice of orthodontics it is of great value to observe the dental development of children for a considerable time before treatment procedures are undertaken. This opportunity of obtaining longitudinal records was of particular value in the study of submerging deciduous molars. It was possible to obtain longitudinal records of the progress of this condition in a number of patients.

A typical example of submerging deciduous molars is illustrated in *Fig*. 3. The patient was a girl under observation for an anterior open bite. No history of thumb- or finger-sucking was obtained, and only mild tongue-thrusting behaviour was observed. A high Frankfurt-mandibular-plane angle lent support to the concept that here there was an abnormal skeletal form leading to this anterior open bite. The models illustrated are taken at a 3-year interval, and it may be observed that on the patient's right side the $\overline{\text{E}}|$ has continued to lose

occlusal height, while $\underline{E|}$, which was in normal position, has started to submerge. The $\underline{D|}$ and $\overline{D|}$ which were in severe infra-occlusion have been shed and the premolars have erupted, if not into occlusion, to the level of changing environment to which the erupting teeth must accommodate. The direction of growth is downward to the Y axis and the degree of anterior open bite has remained constant.

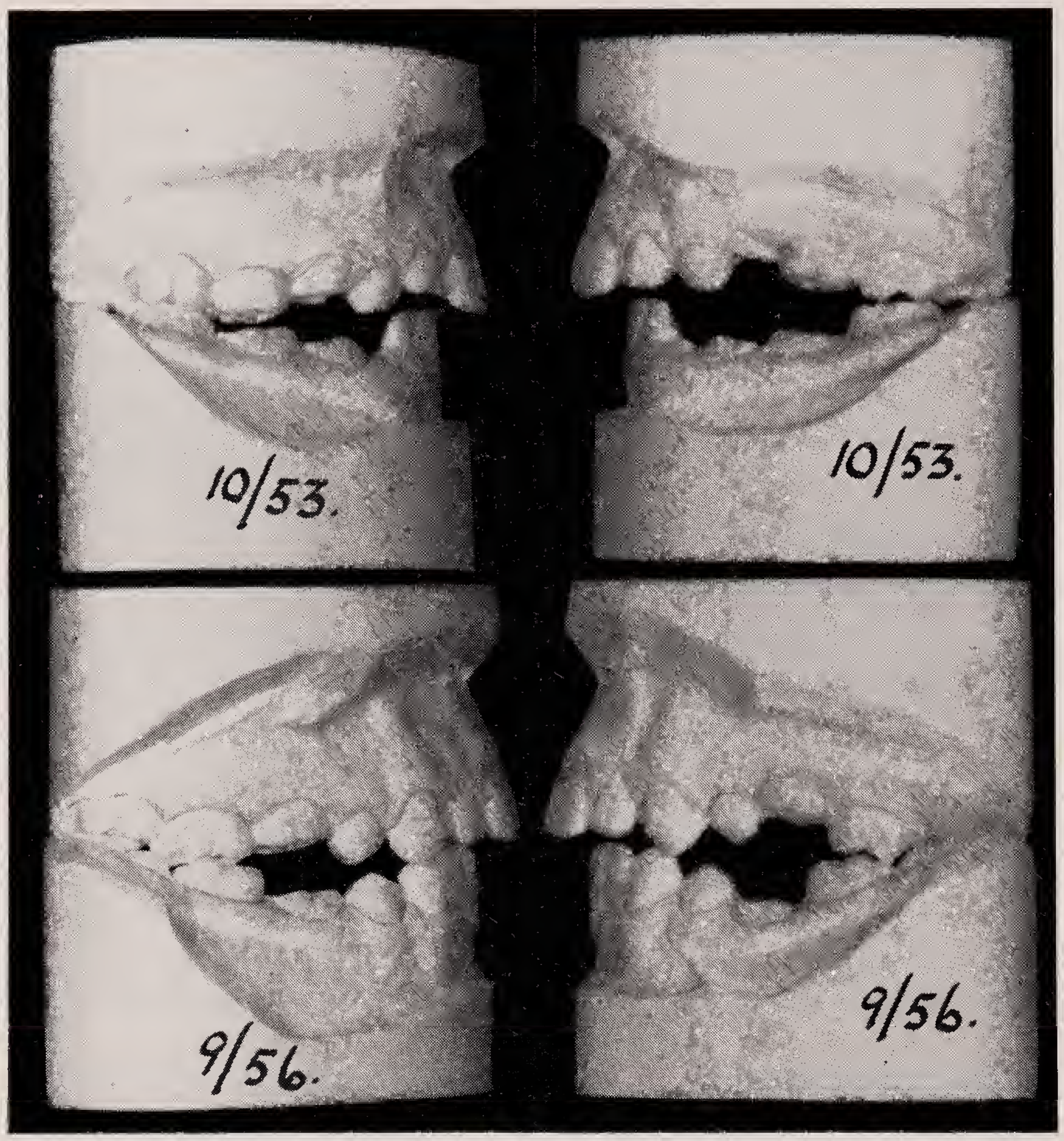

Fig. 3.—Serial study casts of submerging deciduous molars.

the other teeth of each respective arch. A similar position can be seen on the left side of the models. In particular the $\underline{|E}$, which was level with the adjacent first permanent molar, has submerged so far as to give the impression that this may have been an active process and not just a passive loss of occlusal height.

Fortunately, serial cephalometric radiographs were available of the patient just described. Radiographs taken at the same time as the models were traced, superimposed on the sella–nasion (SN) line, as illustrated in *Fig.* 4. Tracing A shows the active growth of the face that is taking place at this period and the

In the second tracing (*Fig.* 4 B) the superimposition is on the submerging $\underline{|E}$. The considerable increase in intermaxillary height is now plainly seen. A slow descent of the nasal floor is also visible. Further, the increase in occlusal distance between the submerging $\underline{|E}$ and $\overline{|E}$ can be seen to correspond to the increase in intermaxillary distance in that vertical plane. Also of interest is the fact that the distance of the occlusal surface of $\overline{|E}$ from the lower border of the mandible is unchanged, reflecting the stability of this region. This supports the concept that the infra-occlusion of these teeth is caused by them being

enclosed by the growth of the surrounding tissue, and not by active tooth movement. Further, it may be used as evidence that for a considerable period these teeth can be regarded as fixed points, as suggested by Logan (1949). In spite of this evidence I still cling to the term 'submerged', as the term can be used in the passive sense of the tooth being covered by a tide of alveolar growth. There was insufficient evidence to make any conclusions with regard to mesial drift of either the submerged molars or the adjacent teeth. This is a subject which deserves further full investigation.

Inspection of a further series of models available revealed a further interesting possibility. In the models illustrated in *Fig.* 5 the lower second deciduous molar, which in the first model is some 4 mm. in infra-occlusion, has in the second model regained its occlusal position. In the third model this tooth is in slight supra-occlusion and in the final model has been succeeded by the second premolar.

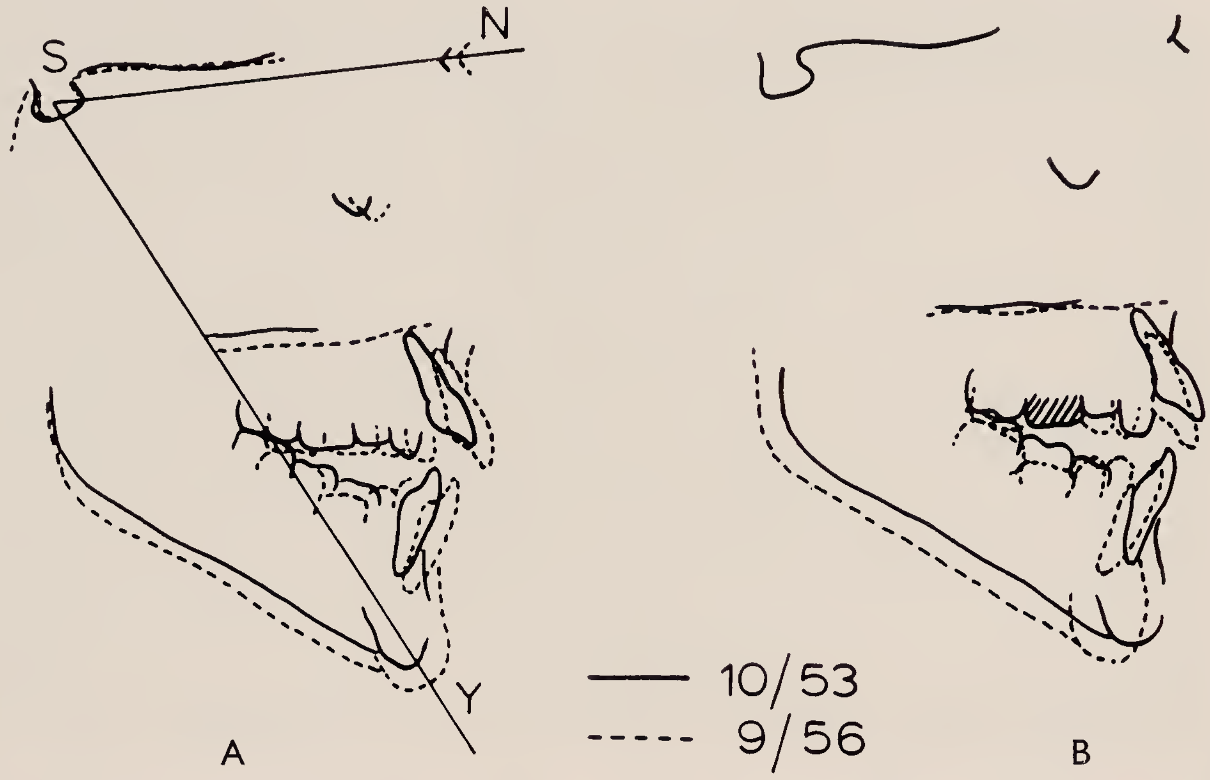

Fig. 4.—Cephalometric tracings of a patient with submerging molars. A, Superimposed on SN; B, Superimposed on $\underline{|E}$ (shaded).

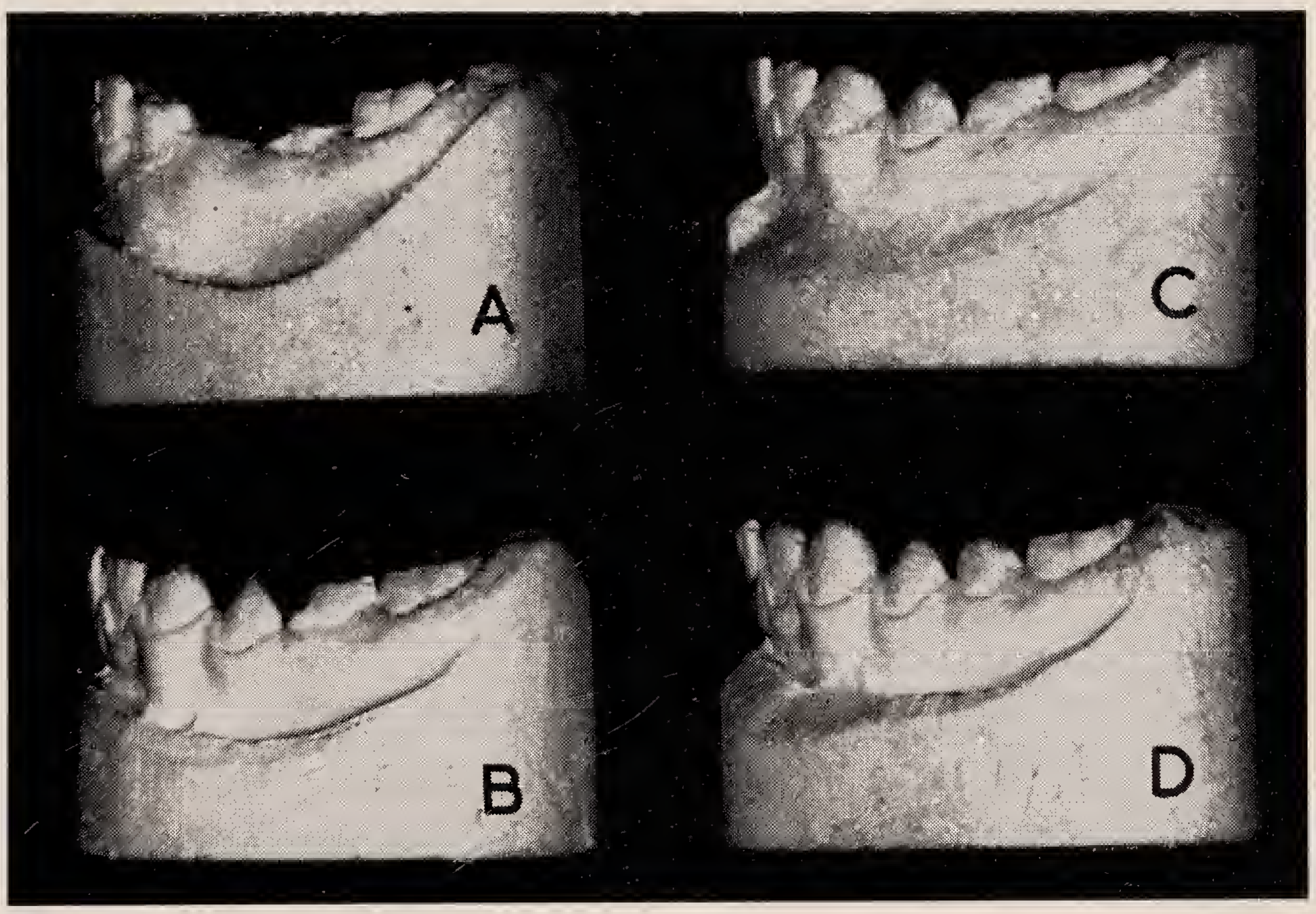

Fig. 5.—Study casts of extrusion of a submerging deciduous molar. Cast A, 10 years 12 months; Cast B, 11 years 3 months; Cast C, 11 years 4 months; Cast D, 11 years 9 months.

This extrusion of a submerging deciduous molar shows that in favourable circumstances the attachment of a submerging deciduous molar to the underlying tissue can be resolved. This may have occurred in this instance due molar has become some 3·5 mm. in infra-occlusion relative to the first permanent molar. This is more than would be expected from a growth anomaly in this period of time, and can be best explained as due to the tooth

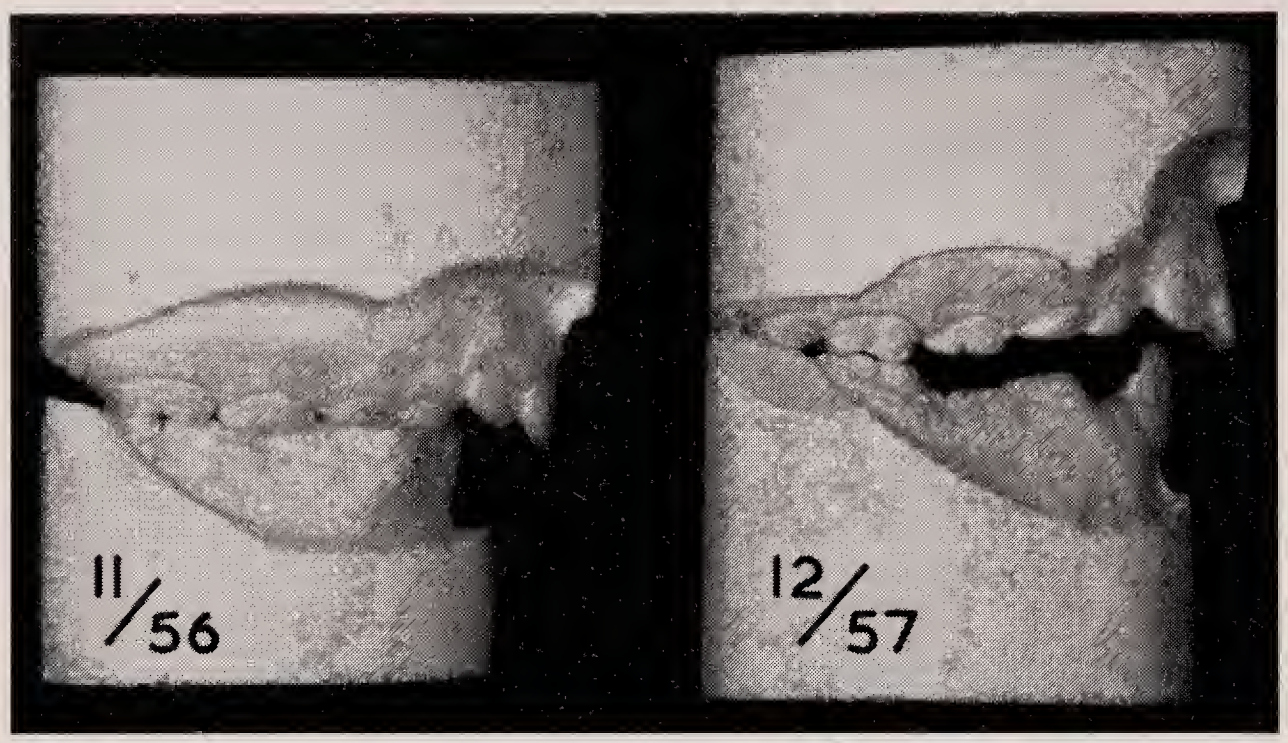

Fig. 6.—Study casts showing effect of functional therapy on occlusal level of deciduous molars.

to the influence of the eruption of the underlying premolar, but this phenomenon is also seen occasionally when the premolar is absent. It is apparent on observing many of these cases that the great majority of such teeth are shed naturally. Only when such a tooth becomes impacted do the deeply buried teeth, such as in *Fig.* 1, result. Re-eruption of submerged teeth may sometimes be stimulated by rocking the tooth if this is done during a favourable growth period.

A number of comments on the effect of orthodontic treatment on submerging deciduous molars have been recorded. Visick (1944) describes a case in which an attempt to move such a tooth only resulted in movement of the anchoring teeth. Such an experience tends to substantiate the finding of ankylosis of these teeth.

In the case to be described, orthodontic treatment appeared to precipitate the condition. The patient, a boy aged 9 years, was under treatment for a disto-occlusion, and an activator was being worn at night. The models in *Fig.* 6 show the condition before treatment and after 1 year of active treatment. It can be seen that the lower second deciduous failing to react to the change in vertical dimension induced by the activator. The lower first permanent molar has erupted to maintain an occlusal relationship, but the deciduous molar had insufficient eruption potential to keep in step. This effect on the deciduous molars is also seen occasionally with the use of an anterior bite-plane. It has also been observed in a case with the upper incisors in lingual occlusion; after correction of the incisor relationship it was noted that the deciduous molars were in infra-occlusion.

In a period when a number of children with submerging teeth were examined or being kept under observation a clinical impression was gained that certain facial characteristics were frequently present. The facial types of these children were often found to be associated with considerable vertical facial height or length. Three children with this tendency are illustrated in *Fig.* 7, and it can be seen that this tendency was found in patients with different dental base relationships. The anomaly of submerging deciduous molars is also observed occasionally in patients with facial dysplasias, and Gaard (1961) reported a patient with cleidocranial dysostosis and

excessive vertical development of the face and submerged lower deciduous molars. I have noted it also in patients with cleft palate, usually in cases with an underdeveloped maxilla.

Fig. 7.—Profile photographs of children with submerging deciduous molars, with different dental base relationships.

It is interesting to review the facial form of the various races of Man. Björk (1947) states that there is a negative correlationship between vertical and sagittal facial dimensions, that is, the greater the facial prognathism, the smaller the facial height. This tendency is illustrated in *Fig.* 8, taken from Stibbe (1930). The Australian Aborigine type shows extreme facial protrusion with a small facial height, while the Negroid skull has a considerable facial and alveolar protrusion with a moderate facial height. In the orthognathous races the Mediterranean type has small facial dimensions while the Nordic type shows facial retrusion with a considerable facial height. Also, both the Mongoloid and Alpine racial types (not illustrated) show group characteristics, while in all races considerable individual variation occurs. Lasker (1960) has recently shown, what often has previously been suspected, that the effect of migration into communities is to increase the variability of morphological measurements. He showed, in three north Peruvian villages with low admixture rates, that variations in bodily measurements were higher in offspring of one or more immigrant parents than in offspring of natives.

It is a feature of the European that immigration and inter-breeding of the various races have occurred since earliest times. MacKenzie (1922) records that before Neolithic times, as well as the primitive Cro-Magnon Man, there were, in Great Britain, Iberians similar in morphology to the inhabitants of Egypt and Somaliland, also Northerners and Armenoid races, the latter being of Alpine characteristics.

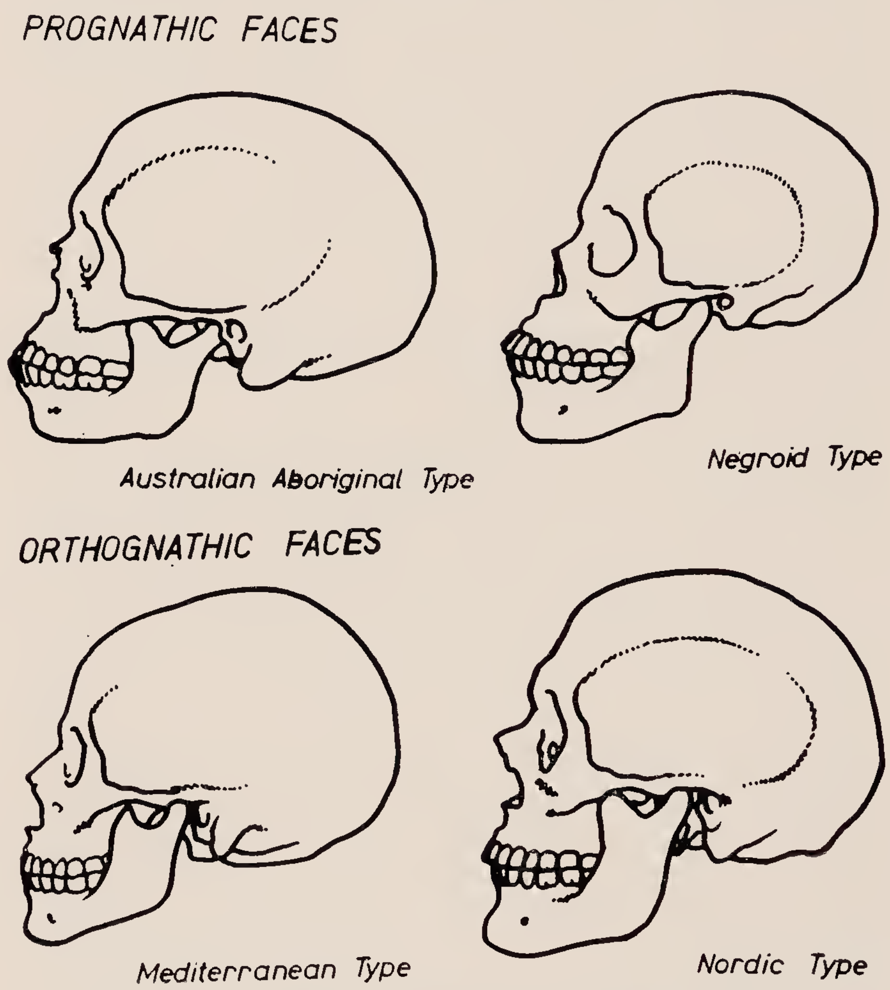

Fig. 8.—Typical facial and skull forms in the prognathous and orthognathous races of Man.

Later came the well-known invasions of Celts, Romans, Anglo-Saxons, and Danes amongst many, giving now an essentially long-faced or leptoprosopic race, but with many individual variations. In civilized man, compared with primitive man, there has been a great increase in malocclusions (Keith, 1925), and much attention has been focused on the effect of evolutionary shortening of the jaws and its effect on arch relationship and overbite, with the tendency to tooth crowding. A feature in the mixed dentition in civilized man is the lack of proximal attrition which in primitive man reduces the deciduous molars to the size of the premolars. With the evolutionary crowding tendency and the lack of proximal attrition, a considerable compressive pressure must result on the deciduous molars situated between the erupting permanent molars and incisors. This can often be observed with the first permanent molars overlaying the submerging deciduous molars, as in *Fig.* 2, and it may be a contributory cause.

Table II.—Proportion of Dental Height to Total Face Height

Patients	1	2	3	4	5	6	Mean Values
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Control series	56·3	56	59·4	53·9	59·8	58·5	57·8
Patients with submerging deciduous molars	61	58·3	53·4	62	60·8	60·1	60·3

It is surprising that although the effects of an evolutionary reduction on jaw length are often discussed, little is to be found on the possible consequences of a relative increase in facial height. Hunt (1961) considers that in civilized man a more intense growth in the upper facial structures occurs and that the eruptive distances of the teeth are therefore greater than in primitive man. Todd and Lindala (1928) found some evidence that upper face length and total face length were more variable in the American white than the American negro; although both populations were diverse, the white material was probably more so. Goldstein (1936) found that facial height was the most variable of the facial dimensions in a growth study in American Jewish children.

The children examined with submerging deciduous molars included 6 for whom cephalometric radiographs were available. In his small group it was possible to make measurements of the facial form and to test the clinical impression previously mentioned. For this purpose the data provided by Brodie (1940) were used. His team of investigators found that in patients with many types of malocclusions the nasal height as a percentage of the total face height was very stable at 43 per cent. This finding has been criticized by Scott (1955) and others, but can be used as an average figure. Therefore the dimension which may be called the dental height, i.e., from anterior nasal spine to menton, should, on Brodie's figure, show an average of 57 per cent of the total face height from nasion to menton. These measurements were now made on the 6 cephalometric radiographs available and compared with 6 control radiographs taken at random from the orthodontic files. The results are shown in *Table II.*

Thus, in this small series, although a wide range of individual values was recorded, the mean dental height in the group of children with submerging deciduous molars was 2·5 per cent greater in proportion to the total face height than that found in the control series. A further measurement which can be made with advantage on children of different ages is that of the Frankfurt-mandibular-plane angle. In the group of 6 children under study this averaged 32·6°, being above the normal range of 17°–28° given by Downs (1948).

No conclusive statements can be made from this small series. A statistical approach to a group this size would be misleading. It must be stated that no absolute correlation between submerging deciduous molars and the dimension of the dental height is maintained. The condition can be found in patients who do not have the facial characteristics described. However, the findings are suggestive that here may be a further factor in many cases which may contribute to a failure of harmony

between the eruption potential of these teeth and the growth of the face. A relationship between submerging teeth and malocclusion also becomes understandable, as does a familial tendency. The underlying agent may well be miscegenation, which is a root cause of so many abnormalities of dento-facial relationships.

Fig. 9.—Girl aged 9 years. Section from E| 1·5 mm. below occlusal level. Records showed that it had started to submerge within the last 20 months. The position of the tooth is shown in study cast A, *Fig.* 16. Invasion of the tooth by resorptive tissue is seen to be mainly involving the surface between the roots. Osteoid tissue has been laid down into the areas of previous resorption and ankylosis has resulted. Active osteoclasts with lacunae formation can be seen in the deeper areas of invasion of the dentine. A small area of resorption on the lateral root surface can be seen above the termination of the cementum, but there are no osteoclasts in this area and it is lined with bony reparative tissue. The pulp is not disturbed or participating in the tissue disturbance. (×15.)

This section of the study can be termed mainly speculative in character and designed to open the subject to further investigation. However, there is one further aspect of the subject which is open to direct observation and that is the histopathology of the abnormality.

HISTOPATHOLOGY

The commonly accepted cause of submerging deciduous molars is the presence of an ankylosis or bony union between the tooth and alveolus (Stones, 1956). That this occurs cannot be disputed as it is frequently found on extracting such a tooth that an audible crack is produced. However, many features of this ankylosis have yet to be revealed, not the least being the reason for its formation. Biederman (1962) comments that neither pressure nor injury with a bur will induce ankylosis of a tooth.

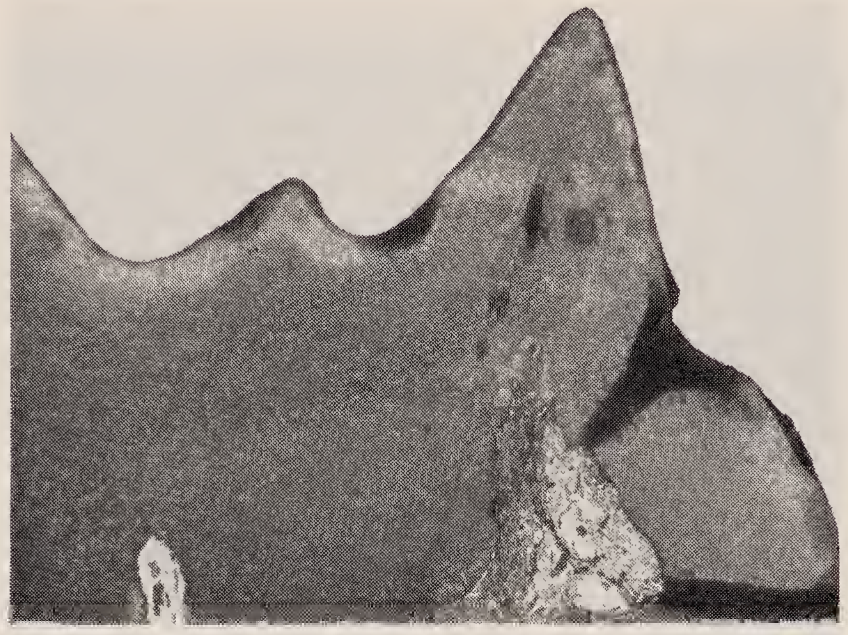

Fig. 10.—Boy aged 9 years. A section from an E| some 3 mm. in infra-occlusion. In this slide the soft-tissue invasion has replaced the pulp tissue and extensively attacked the dentine above the pulp cavity. Fingers of resorptive tissue are undermining the cusps and many osteoclasts can be observed. There are some areas in which osteoid tissue has been deposited, but thc main activity shown is of resorption. (×15.)

To investigate further the histology of this condition, serial section technique was undertaken on 10 examples of submerging deciduous molars. Also 2 deciduous molars in normal position from the same patients were sectioned as controls. Serial sections were considered necessary as the histological appearance may vary considerably in different regions of the same tooth, and further to ensure that no area of ankylosis was missed. Sections were cut at 7 μ after embedding in paraffin wax, and staining was with routine haematoxylin and eosin.

The investigation showed that an outstanding feature of the early stages of the condition is the presence of areas of resorption with considerable osteoclastic activity. This is seen in *Fig.* 9 where the inter-radicular surface is involved. A later stage is visible in *Fig.* 10; here the resorption has continued and has undermined the cusps. This is a very active form of resorptive activity with long finger-like processes penetrating into the dentine. The resorption can continue, and if the tooth

is not shed it will take on a pinkish shade. In many respects this histological process is not dissimilar to that of the condition known as 'pink spot'. It appears that the tissues are removing a tooth which is no longer fulfilling

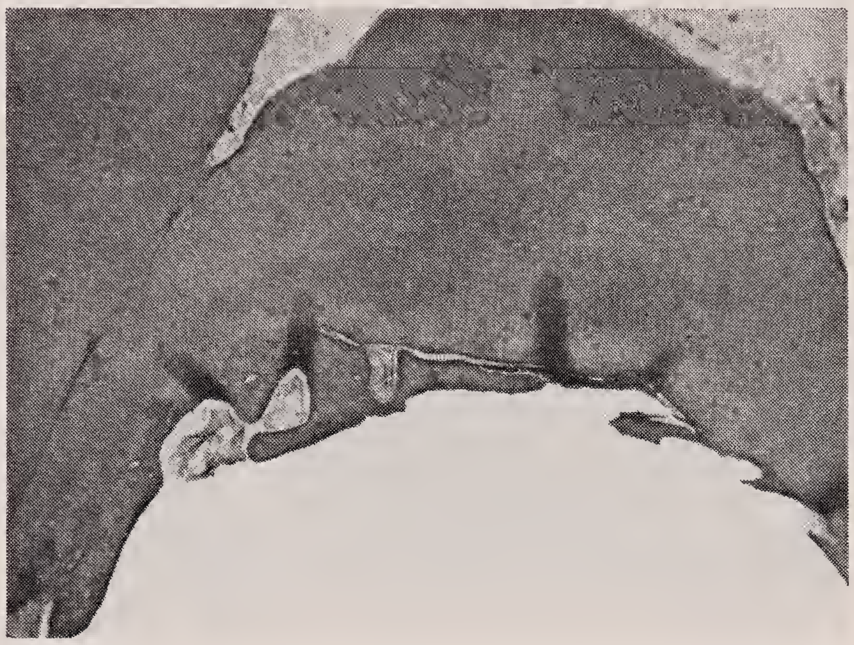

Fig. 11.—Boy aged 11 years. This slide is of an $\overline{\text{E}|}$ some 4 mm. in infra-occlusion. It has been separately illustrated as there is no succeeding premolar present to influence the histological picture. The position of the tooth can be seen by reference to study cast B, *Fig.* 16. A similar picture is evident as in the previous slides of submerging molars. Areas of active resorption are seen with osteoclasts present. The ankylosing bone is again deposited into areas of previous resorption, mainly between the roots. It is interesting that the ankylosed bone that has adhered to the tooth after extraction has restored the outline of the root shape. (×15.)

its biological role. Finally, the tooth may disintegrate from the resorptive process if not shed, and all that remains is an area of abnormal tissue. This may persist if there is no succeeding tooth, and explains the appearance known as phantom socket described by Logan (1949).

The resorptive process is usually closely followed by a deposition of osseous tissue. This osseous tissue is similar but not identical with bone, as shown by Vorhies and others (1952). The deposition of this osseous tissue into the previously resorbed areas is the mechanism of the formation of the ankylosis. This deposition of bony tissue replaces the tissue of the tooth and may be described as a replacement ankylosis.

This process is not affected by the absence of the succeeding premolar tooth. A similar histological picture is visible in *Fig.* 11, showing a submerging second deciduous molar from a patient with agenesis of second premolars. A high-power view of a portion of the inter-radicular surface of this tooth is illustrated in

Fig. 12.—A high-power view of a section through the tooth illustrated in *Fig.* 11. An area of active osteoclastic activity is seen to precede the laying down of ankylosing bone. Several osteoclasts can be seen in Howslips lacunae in the dentine. The bone-like tissue is of an undifferentiated calcified matrix, with the inclusion of a number of osteocytes. (×90.)

Fig. 13.—$\overline{|\text{E}}$ normal position. The same patient as the previous specimen shown in *Figs.* 11 and 12. The $\overline{|5}$ was also absent and the positions of both teeth sectioned are shown in *Fig.* 16 B. Normal histological picture with the inter-radicular root surface is covered with a thin remnant of the periodontal membrane. Small areas of resorption activity can be seen, but no ankylosed bone is present. (×15.)

Fig. 12. Osteoclasts can be observed in the area of resorption in the dentine. Enclosing this area of resorption is a layer of ankylosing bone. As a control to the normal histological

appearance at this stage a section from a deciduous molar in normal occlusion, extracted simultaneously from the same patient as the preceding specimen, is illustrated in *Fig.* 13. Only a low order of resorptive activity is seen,

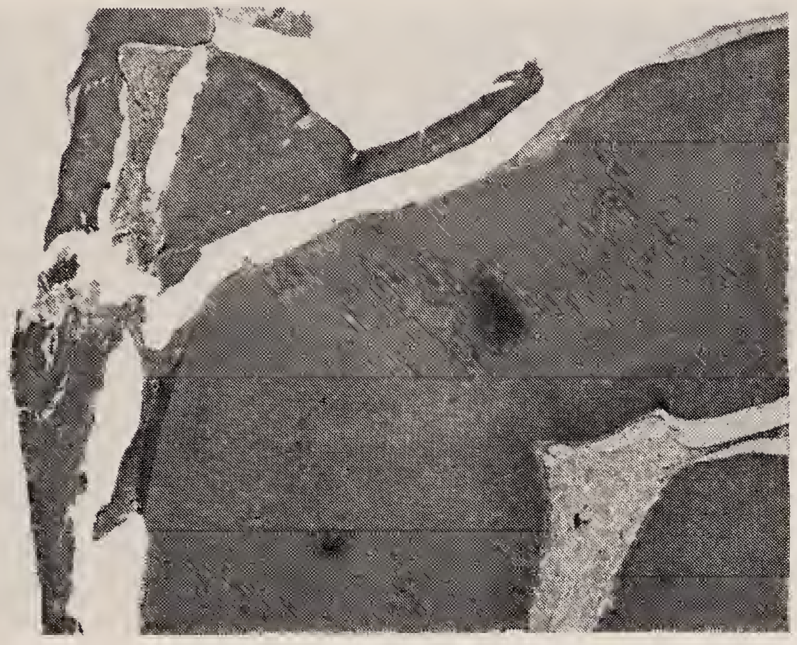

Fig. 14.—E|, also from the same dentition shown in *Fig.* 16. This tooth was submerged some 4 mm. and was extracted surgically together with a portion of labial alveolus. The histological appearance is essentially normal. Both roots have been removed by resorption, and a few osteoclasts are visible. The alveolar bone has a normal appearance with some differentiation into compact and cancellous bone; also a number of small Haversian systems can be seen. No evidence of ankylosis was seen in any section examined of this tooth and the root surface was continuously covered with soft tissue. (× 15.)

with mononuclear cells present instead of osteoclasts.

One submerging deciduous molar had its root surface continuously covered with periodontal membrane with no sign of an ankylosis (*Fig.* 14). A portion of alveolus was removed with this tooth, and this also had a normal histological appearance. As with this section many submerging deciduous molars appear to reach a state of relative tissue inactivity, as complete resorption of these teeth occurs only occasionally.

Skillen and Walley (1937) also observed that these teeth may not invariably be ankylosed. They commented that the roots of such teeth are covered by a thin layer of cementum. This, however, was not present in one specimen, but it was observed that the cementum on the lateral root surfaces appeared to resist resorption, which mainly occurred on the inter-radicular surface.

It is important to note that Kronfield (1949) stated that an ankylosis can occur during the intermittent processes of resorption and deposition which occur in the resorption of a deciduous tooth. This investigation supports

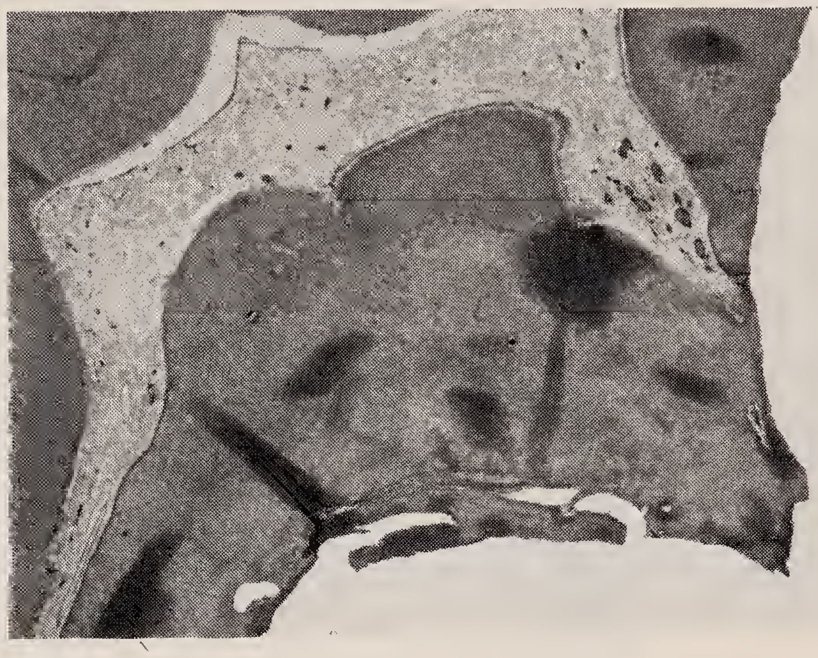

Fig. 15.—A section from an |E from the same patient as the preceding specimens. However, this tooth was in normal occlusion. The position of the tooth is shown in *Fig.* 16 A. An area of ankylosis can be seen between the roots with a layer of bone attached directly to the dentine. A small segment of periodontal tissue can be seen surrounded by the ankylosed bone. Little resorption activity can be seen; evidence of previous resorption is visible in the scalloped edge of the dentine, to which the ankylosed bone is attached. This is the classical picture of ankylosis. It is interesting that it is of bone attached to a tooth in normal position, and in both respects contrasts with the previous specimens. (× 15).

this view, and *Fig.* 15 shows such an area of attached alveolus found in a control tooth. The ankylosis is of a different type from that seen with the preceding submerging molars; it is not replacing part of the tooth but is attached to it. The essential difference was the different form of the resorption which preceded the ankylosis.

SUMMARY

The total findings of this study can be stated as showing an incidence of up to 2·5 per cent of children showing submerging deciduous molars with an even higher incidence found in a group of children under orthodontic care, with, however, no relationship shown with any single type of malocclusion. The condition was frequently bilateral and often more than one tooth in each dentition was involved in each

patient; no single local factor could explain the clinical appearance observed.

Cephalometric tracings showed that the loss of occlusal height of a submerging molar was related to the rate of facial growth of the child. The association of submerging deciduous molars with the bite-raising action of functional appliances underlined the intimate relationship between eruption potential of such teeth and the intermaxillary dimension. An hypothesis has been presented that submerging deciduous molars are more frequently found in children with a large vertical dimension as part of their facial morphology. In these children it is suggested that the growth of alveolar ridge and eruption of decidous molars may be inadequate at certain periods of active growth to bridge the rapidly increasing maxillo-mandibular dimension.

An extremely active resorption of the teeth was an early histological picture, and this was followed by a deposition of osteoid- or bone-like tissue replacing the tooth structure and forming an ankylosis. Such an ankylosis was usually present, but one deeply submerged tooth proved to be an exception. A similar examination of a small control series of deciduous molars in normal occlusion revealed a further example of ankylosis, but of a different type to that seen with submerging deciduous molars. It is considered that ankylosis is not the primary cause, but part of the tissue reaction to a submerging tooth. When formed, however, an ankylosis can act as a secondary impediment to further eruption.

It was concluded that although local factors may precipitate the condition in individual teeth the underlying cause of submerging

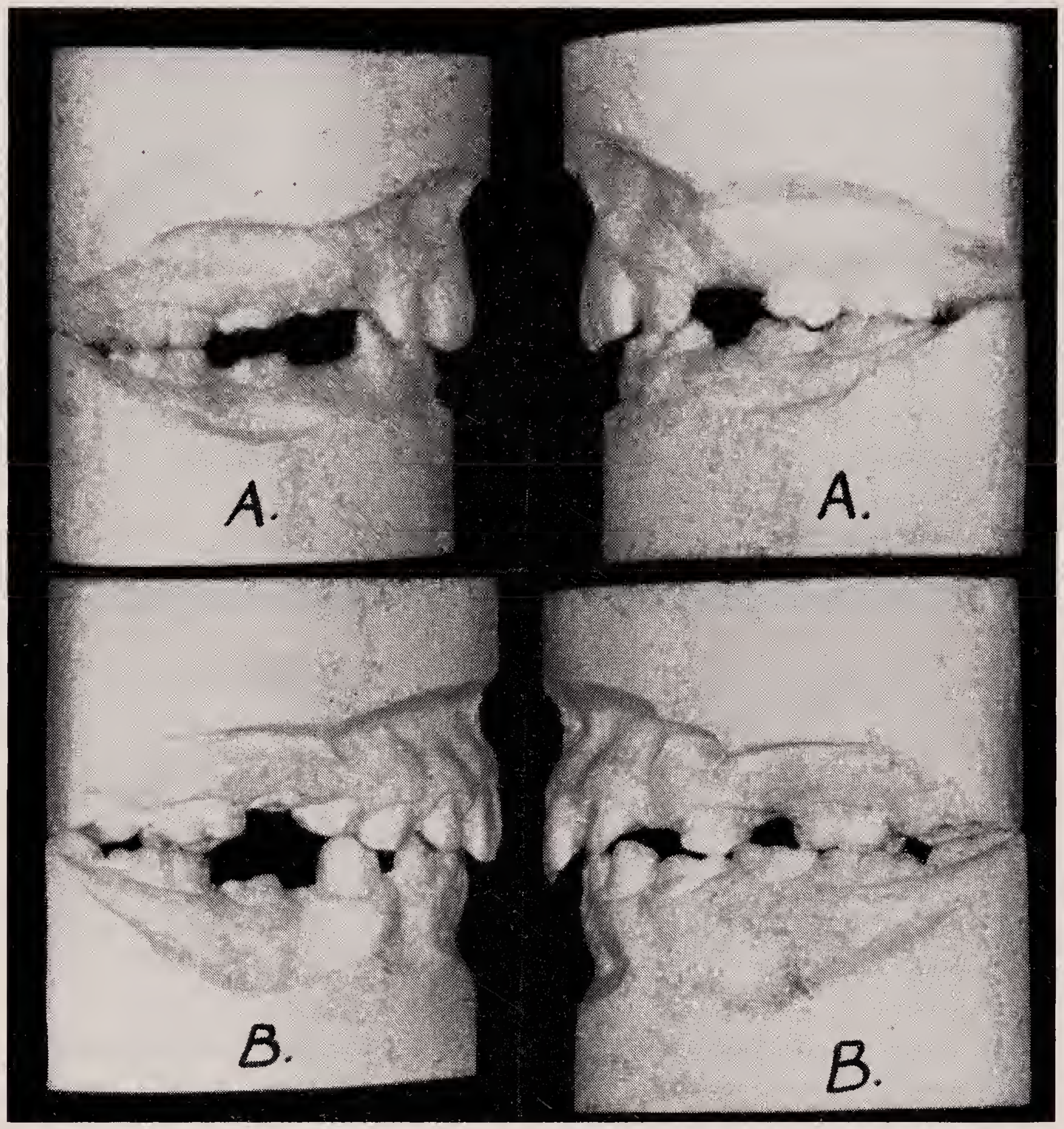

Fig. 16.—Study casts of dentitions with submerging deciduous molars from which histological preparations were made.

deciduous molars is an anomaly of eruption, due to the failure of the eruption potential of these teeth to relate to the rate of facial growth. It is hoped that this study will stimulate interest and further investigation into this subject, which has important implications as a keyhole through which the process of growth of the dento-facial region may be observed.

Acknowledgements.—I wish to express my thanks to Dr. G. B. Hopkin and Dr. W. Russell Logan for their advice and encouragement, and also to Mr. C. P. Wallis for many suggestions and help with the statistical problems of the study.

I am grateful for the work undertaken in preparation of the histological specimens, together with the photography and mounting of this material, by Mr. A. Hunter, Mr. B. Cooney, Mr. R. Renton, and Mr. W. A. Duncan. Without the facilities provided by the Edinburgh Dental Hospital and School, and the help of these and many other members of the staff this study could not have been entertained.

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DISCUSSION

Dr. W. J. Tulley, opening the discussion, said that he wished to congratulate Mr. Dixon on his excellent paper and for winning the first Chapman Prize.

He thought that everyone agreed that there were phases of ankylosis and resorption of the teeth and that many of them erupted, given the fact that they had successors and given the fact that they were not impacted irreparably. He wondered whether distinction should be made between single examples and those cases where both deciduous molars in all quadrants were slightly submerged. Some authorities had blamed tongue position for that. He could not agree. He thought that the ankylosis was probably the primary factor.

Mr. Dixon did not say how many of the 400 primary schoolchildren had in fact got some degree of malocclusion in the first sample: could he help on that? He had been intrigued with Mr. Dixon's finding of a high incidence in cases with high Frankfurt-mandibular-plane angle with increased anterior face height. He felt Mr. Dixon's small sample was misleading in that instance, but it was only a working hypothesis.

He had seen cases of brother and sister and identical twins with such submerged teeth, which lent authority to other writers on the subject.

Mr. E. K. Breakspear said that Mr. Dixon had observed that the condition occurred more often on the right side than on the left in the proportion of 4 : 3 and that that was the same in all the four groups studied.

He himself had presented some results to the Society two years ago, in which he pointed out that the left side of the face, on the average, behaved as if it was in some way compressed, compared with the right side. It appeared that it was smaller so far as the teeth were concerned and therefore in closer apposition with the tongue.

If the condition of submerged molars was due to impaction primarily, then it would occur more often on the left side; in point of fact, it was observed more often on the right side and that would be consistent with a growth factor rather than a local factor.

Mr. A. J. Walpole Day asked if Mr. Dixon had observed the condition in any other teeth. The paper referred to

submerged molars, but he had seen submerged canincs. He had not seen any submerged incisors.

Mr. H. E. Wilson said that it was a great pleasure to him to see that the first recipient of the Chapman Prize was one of Mr. Chapman's old students.

It seemed to him that there was no one factor at all, because people had discussed possible different factors. One got some deciduous molars being completely submerged and, if the space was opened for them, they would re-erupt. Yet one would find in other cases, where there was sufficient space, that they sometimes did not erupt. His belief was that there was a physical element, that the second deciduous molar was, in fact, held down by the adjacent tooth. When the space was re-created, very often, but not always, the deciduous molar would erupt. While Mr. Dixon did not specifically state so, it had to be remembered that the ankylosis need not be general and might be in one spot only. Therefore, although it was not obvious from histological examination, that was not to say that it was not always there.

Mr. S. G. McCallin wondered whether the problem was not basically one of anteroposterior arch length development and there was not some disturbancc in the distance between the first permanent molar and the deciduous canine.

Mr. J. C. Stephenson asked how fixed Mr. Dixon thought the position of the submerged tooth was. He understood that some people had measured the growth-rates or velocities of eruption of other teeth in the same jaw by using a submerged tooth as a fixed point.

Mr. B. B. J. Lovius asked if Mr. Dixon had measured the relative mobility of the submerged tooth in relation to the other teeth. That should be quite a good guide as to the amount of ankylosis affecting the tooth.

Mr. D. A. Dixon, in reply to Dr. Tulley's comments, said he certainly distinguished abnormalities of single teeth and felt that local factors here played a part; certainly impaction could do so with submerging lower first permanent molars. But so many cases were bilateral and multiple that one had to look for a general factor as well. He did not agree that ankylosis was a primary factor on the evidence established at present. A number of teeth were shown to be at some periods without ankylosis. Approximately half had malocclusions in the first group, more than one would expect from the usual percentage.

He agreed that tongue-pressure did not appear to explain the condition. The fact that in many cases the premolars erupted normally after the deciduous molars were lost was significant.

He had forgotten Mr. Breakspear's observations on the development of each side. He did not think too much could be made of his figures at the moment; a difference of 4 to 3 was not really significant.

On the point about anteroposterior arch discrepancy he had shown one slide where the tooth appeared to be compressed between the adjacent anterior tooth and posterior tooth, and he agreed with Mr. McCallin's observation.

With regard to the points raised regarding the fixed nature of such teeth, trying to trace such teeth on cephalometric radiographs was an exhausting business, and he would not like to make any comments on its accuracy.

In reply to Mr. Walpole Day, he said that he had seen one or two incisors showing that appearance, but they were resorbed and shed fairly early on. It was not infrequently seen after re-implantation of permanent incisors.

On Mr. Wilson's points, he said that there was probably an individual potential of eruption varying between different groups of teeth, if not individual teeth. Lower deciduous molars were more often seen in that position than other teeth, primarily because lower second premolars were often absent. The possibility of a single spot of ankylosis was difficult to eliminate, but he had attempted tc do so by using a serial seetion technique.

He did not think he could do better than by ending with Mr. Chapman's comment made some twenty years ago on the subject. He said: 'In the vast majority of these submerged teeth, one would consider that they are just a variation of the normal.'

TRANSPLANTATION OF LOWER THIRD MOLAR TO FIRST MOLAR SITE

By D. S. HAYTON-WILLIAMS, M.R.C.S., L.R.C.P., L.D.S.
Churchill Hospital, Oxford

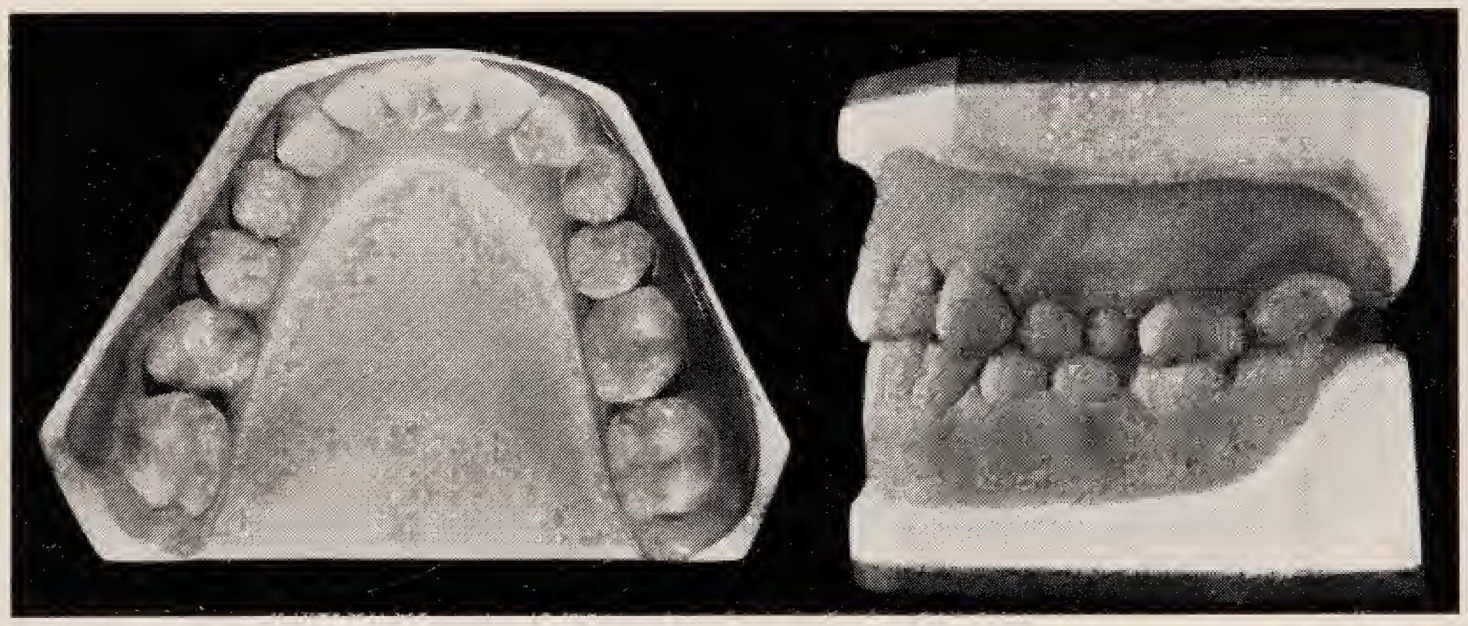
A GIRL aged 14 years was referred to me in 1958. There was a filling and also extensive caries in |6. The pulp might become exposed. The referee was wondering whether to treat the tooth or to extract it, in which event there would probably eventuate a tilting of |78 (*Fig.* 1 A). I felt it justifiable to transplant |8 into |6 region.

Prior to operation under general endotracheal anaesthesia, an acrylic plate was made so as to cover the transplanted tooth site, i.e., the |6 area. Wires were incorporated so that when acrylic material was cut away to permit eruption of the transplanted tooth, they would prevent backward drift of |5 and forward drift of |7.

A radiograph of the tooth after transplanting is shown in *Fig.* 1 B.

A B C

Fig. 1.—Radiographs of |8 seen, A, Before transplanting; B, Immediately after transplanting; and C, Two years after operation.



A B

Fig. 2.—Acrylic models of the dentition showing the transplanted tooth 2 years after operation. A, Occlusal view; B, Lateral view.

The new tooth now has a filling in it. It responds to electrical pulp test similarly to the corresponding vital lower right first molar. The present condition (1962) is shown in *Figs.* 1 C, 2.

At operation it was necessary to cut away sufficient bone so as to permit easy lifting out of |8 with its follicle. Quite a lot of bone

Given at the meeting held on 8 October, 1962.

removal from $\overline{|6}$ socket was necessary so as to accommodate the $\overline{|8}$ and to permit close suturing of mucoperiosteum. As would be expected there was considerable postoperative oedema and limitation of jaw separation.

I think it highly desirable to close in the transplanted tooth with well-sutured mucoperiosteum, and also to protect the suture line from trauma. Good oral hygiene is essential, as following any oral surgery.

It is not an operation to undertake lightly and in my opinion should be performed only on a co-operative patient who has a high standard of oral hygiene.

DISCUSSION

The President said that the case described by Mr. Hayton-Williams was most remarkable. It would be remembered that with the ordinary transplantation of teeth, which was done frequently at one time, the teeth were extracted from one person and put into another. It was generally found that the roots became absorbed in 3 to 4 years' time, and it was believed that that was due to the lack of periodontal membrane. Had Mr. Hayton-Williams any thoughts as to the generation or regeneration of periodontal membrane because, obviously, some form of root was forming.

Mr. Hayton-Williams, in reply, said that, regarding the periodontal membrane, he did not know. He imagined that there was one.

BONE GROWTH, NORMAL AND ABNORMAL

By Professor J. I. P. JAMES

Department of Orthopaedic Surgery, University of Edinburgh

To have been invited to give this year's Northcroft Memorial Lecture is a greatly cherished honour. The subject chosen is the growth of bone, and it is proposed to survey this in a very general way. The definition of growth is indeed rather sweeping, for it includes the changes seen in structure and chemistry in the adult years even into old age. This is done to show how plastic a substance is bone, despite the superficial impression of an unchanging structure. To you as orthodontists a discussion on bone growth and change will not come amiss as it is a fundamental problem in your therapy. It is likely that Northcroft, your second President, whom we remember in this lecture, would feel that this was an appropriate discourse to honour him.

Bone can increase in size only by appositional growth at its surfaces, its rigidity preventing interstitial growth, which is the means by which almost all other tissues grow. Increase in length takes place at the epiphysial cartilage plate and in width by subperiosteal bone growth. In addition, from the embryo to the aged person constant slow changes are occurring in its internal structure. Initially strengthening in response to mechanical stresses, it is later absorbed as strength is less needed and as metabolism fails in old age. Less obvious, but nevertheless of great importance, are biochemical changes now being resolved with the aid of radioactive isotopes and other new investigative methods.

Orthodontics is greatly concerned with the young developing bones of face, jaw, and teeth. Orthopaedic surgery until a few years ago also gave pride of place to the young. Now the senile porosis of bones is one of the great clinical problems, each year, for instance, causing some 250 fractures of the neck of the femur in the City of Edinburgh as well as large numbers of wrist and other fractures, almost all in elderly females; osteoporosis is more deadly than the motor car.

It is now proposed to review chronologically the bone changes as seen from the embryo to old age.

In the embryo the bones are laid down either as membranous or cartilage models. The earliest bone appears as a ring around the centre of the shaft of the cartilage model, and from this zone vascular tissue, followed by osteoblasts, invades the central part of the cartilage mass to form a diaphysis of bone. The perichondrium now becomes periosteum. Later, secondary centres of ossification develop at the extremities of the bone, separated from the diaphysis by a band of cartilage which now becomes the epiphysial cartilage plate at which all increase in length of the bone will subsequently take place. This first bone will later totally disappear.

At this early stage of embryonic life almost all tissues are susceptible to noxious influences, whether it is the virus of German measles adversely altering the development of the heart, or thalidomide which may arrest the limb buds completely.

Susceptible though it may be to the action of minute quantities of harmful substances or minor physical changes in early embryonic life, the developing bone later shows a remarkable ability to continue its growth and development in the most adverse circumstances. For example, if a bone obtained in late foetal life when it is still largely formed of cartilage is implanted *in toto* into the spleen where it is devoid of muscle pull, it will continue to develop and grow into a recognizable femur.

Further evidence of this remarkable growth potential of cartilage may be seen in an experiment in which transplanted foetal bone growth was compared in hosts of the same inbred strain, so inbred as to be comparable to twins; in these no immunological reaction to the graft developed. Cartilage growth was succeeded by bone growth as in the normal

The Sixteenth Northcroft Memorial Lecture given at the meeting held on 12 Nov., 1962.

course of events, but it became apparent that in the absence of muscle-pulls the secondary characteristics of the transplanted bone tended to disappear, although the grosser features persisted. In the bones transplanted into a host of different strain, the bone tissue falls victim to the immune reaction and fails to survive, whereas the cartilage, by virtue of its avascularity, is protected against this reaction and continues its normal growth (*Fig.* 1). In these transplants the secondary characteristics of the bone were not only formed, but persisted despite the absence of stress (Chalmers and Ray, 1962). Thus it appears that the cartilage precursor of bone is invested with a growth potential capable of forming in detail the features which characterize a specific bone, but that, when bone replaces the cartilage, functional stresses are required for the retention of these features. This is well illustrated in one experiment where the graft was fractured when being transplanted. It healed, but no remodelling took place because there could be no functional stresses in the spleen.

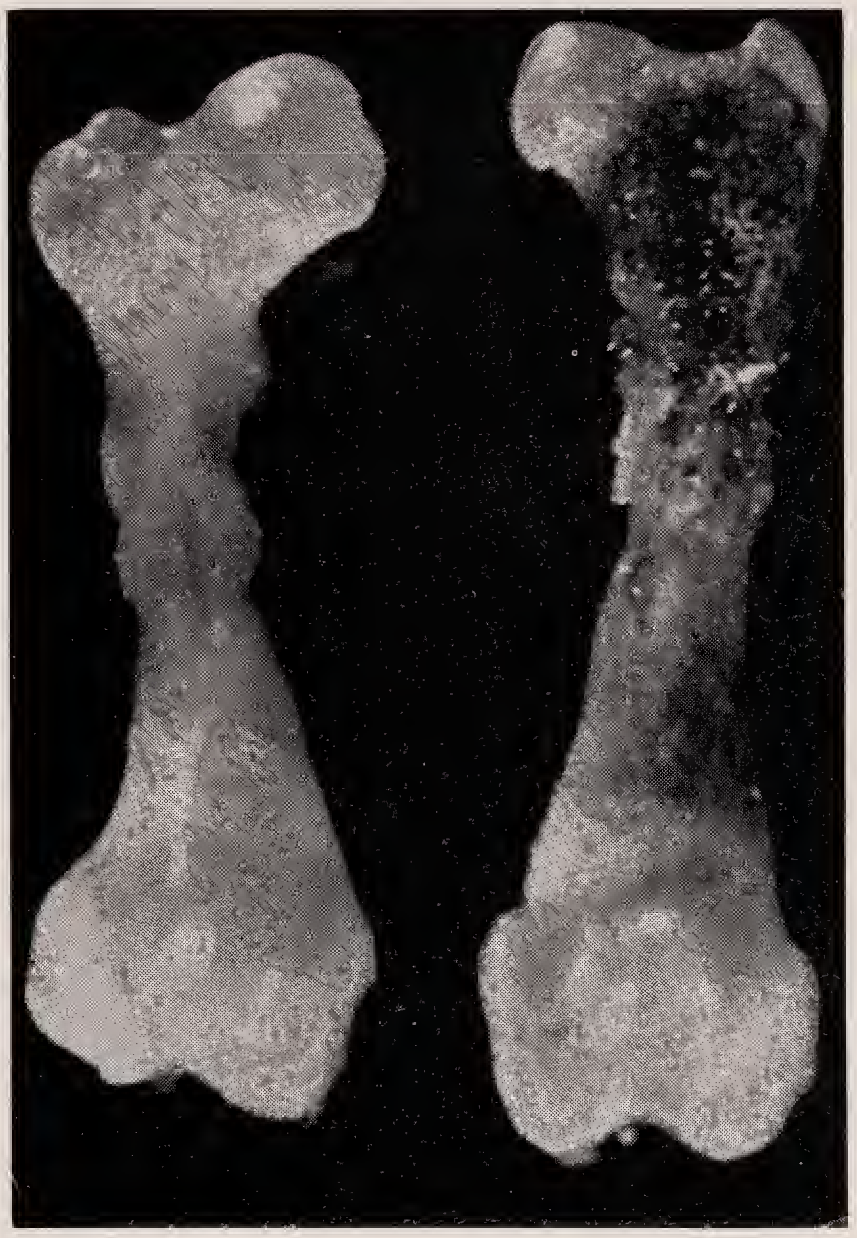


Fig. 1.—The avascular cartilage has survived in both these transplanted femora. The femur on the right was transplanted into an immunologically similar mouse and thus the vascular bone has continued to grow whereas the bone transplanted into a 'foreign' animal has not grown because of the antibody response.

This remarkable phenomenon implies that within the cartilage model is a 'memory' or chemical pattern that organizes the growing bone. By very different means the modern computer automates the making of a car and perhaps the stored electronic pattern of this computer may have something akin to this property of developing bone, or it may be, and there is some evidence for this, more chemical in nature.

In this way the whole problem of organ transplantation is exemplified. Cells from a 'foreign' individual produce an immunity response and are killed. Cells from 'twin' individuals survive, and this is true whether it be a kidney or bone which is being transplanted. Our only method which allows organ transplantation with cell survival between dissimilar individuals is to destroy by X-ray irradiation, or certain drugs, the immunity responses of the host's body, thus also leaving him prey to bacterial infections, against which he is now unarmed (Woodruff, 1960).

The ability to transplant an organ within an inbred group of individuals does, as you see, give us a wonderful research tool for the investigation of the factors regulating this early phase of bone growth.

Despite the numerous problems left unmentioned in embryonic bone growth it is necessary now to proceed to consider bone growth in the child, a stage at which it is clinically and radiologically easy to see bone growth and visualize its mechanism, and yet, it seems, a field in which much is still not known. At this stage bone growth is epiphysial and periosteal.

In the long bones there are usually two epiphyses, proximal and distal, and one is likely to contribute much more growth than the other, and this, as is seen later, presents some interesting problems.

The epiphysial cartilages consist of vertical layers of cartilage cells with the reproductive

layer towards the epiphysis, the most mature cell nearest the diaphysis. The matrix separating these mature cartilage cells becomes calcified. and the degenerate cells are invaded by the capillaries of the metaphysis followed

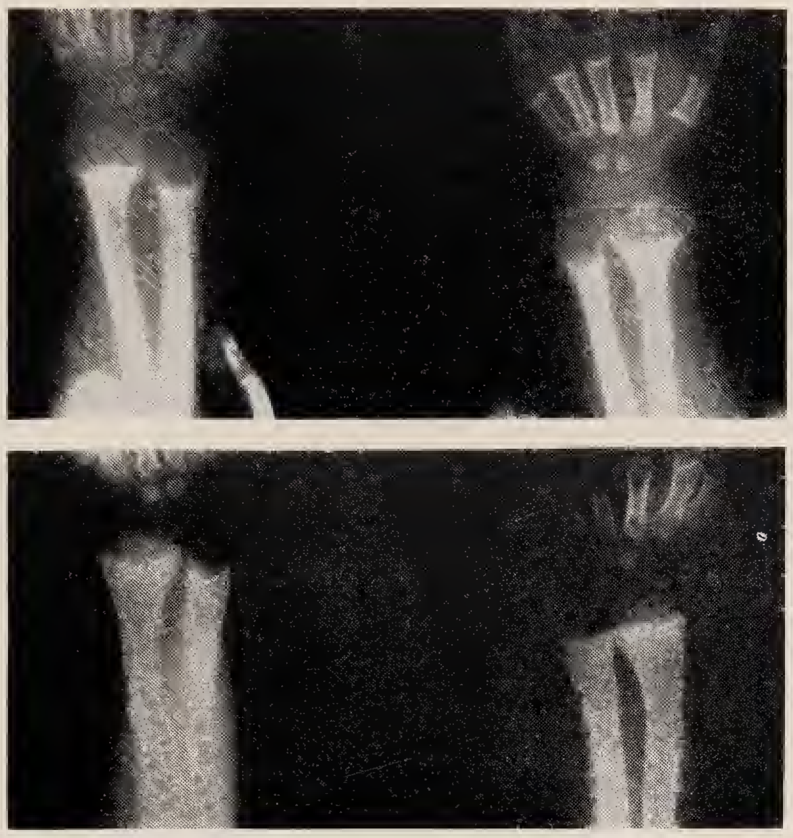


Fig. 2.—The upper X-rays show active vitamin-deficiency rickets with widening of the epiphysis and an increase in its depth. After the administration of vitamin D, calcification and ossification proceed normally and there is a restoration of normal epiphysial growth.

by osteoblasts which lay down new bone upon the scaffold provided by the calcified matrix.

This normal functioning of the growth plate may be disturbed in several ways. In rickets, for example, there is a defect of mineralization which is due to vitamin D deficiency. The maturing cartilage does not calcify, and appears to resist vascular invasion so that it becomes much thicker than normal. At the same time such new bone as is formed is also inadequately mineralized and contributes to the wide zone of translucency which is seen on X-rays of the epiphysial cartilage plate. If the vitamin D deficiency is corrected there is a rapid return to normal (*Fig.* 2).

An interesting abnormality of epiphysial growth has been elucidated by Trueta and Morgan (1954). They noticed that overgrowth of bone was seen more frequently in penicillin-treated osteomyelitis. They also noticed that in patients with overgrowth there was obliteration of the medulla near the nutrient artery; in fact this artery is thrombosed. To replace the blood-flow the vascular network over the epiphysis increases to provide a collateral supply and, like turning up the heating in a greenhouse, the epiphysial cartilage plate overgrows. This is also seen as a temporary phenomenon after dividing the sympathetic nerve-fibres, for this also causes vasodilatation (Harris and McDonald, 1936). Operations to cause short legs to overgrow by blocking the nutrient artery have been tried, but the effect is short-lived for the medulla is recanalized and the vascular supply once again goes the normal way. More successful has been the making of artificial arteriovenous aneurysms which result in an increase of blood-supply and overgrowth.

Equally, pathological changes in the epiphysial cartilage plate may produce premature arrest of growth. Trauma compressing an epiphysial plate and thus breaking down the cartilage line is often the cause of premature arrest, and if the arrest of the epiphysial plate is partial, deformity will result. Infections such as osteomyelitis may similarly destroy an epiphysial plate.

A most interesting phenomenon is the arrest of epiphysial growth that develops when a child is immobilized for more than eighteen months, as was common in the treatment of tuberculous hips and other conditions. It was not rare for such children to develop as much as 8 in. of leg shortening, depending, of course, on the age when the epiphysial growth became arrested. The tuberculous hip produced 1 or 2 in. of shortening by destruction of bone, but treatment by immobilization caused the remainder of the 8 in. loss. It was Gill (1944) who first recognized the phenomenon of immobilization epiphysial arrest. During immobilization, disuse atrophy becomes so extreme that one or both epiphysial plates around the knee perforate centrally and the bone unites through the epiphysial plate (*Fig.* 3).

Congenital absence of the upper end of the femur is not rare and leads to gross shortening due to absence of the proximal epiphysis.

There was much dispute at one time as to whether longitudinal growth occurred solely in the epiphysial plate or whether the diaphysis

could elongate. Metal markers placed in the diaphysis can be shown not to grow apart. Harris (1933) noted that if a child developed a severe illness this was later marked in the long bones by dense lines, the so-called Harris's growth lines. These lines are rather equivalent to the growth rings of a tree in winter compared to summer. Observation of these, if there are several rings, again shows no separation, one from the other, during growth. They also offer an easy method of measuring the annual rate of growth from the epiphysis. On very rare occasions poisoning by phosphorated cod-liver oil given each winter to a baby has produced annual winter-growth lines (*Fig.* 4). There is now proof that in post-embryonic life all the longitudinal growth is at the epiphysial plate.

Fig. 3.—This section of a tibia shows clearly the perforation of the epiphysial growth plate and a central plug of bone which effectively arrests growth. This is an effect of long-continued immobilization.

When a leg is short, it is possible to arrest the long leg by destroying the epiphysial plate by operation and thus permanently arresting it and allowing the short leg to catch up (Phemister, 1933). Leg equalization was ingeniously made more flexible by Blount (1949) who showed that staples inserted across an epiphysial plate could arrest growth until the staples were removed, when it would start again. If one knows the exact amount of leg shortening and the growth to be expected, one can arrest the long-leg epiphysial plate at such a time that, when the child has ceased to grow, the legs will have just become equal. Studies by Green and Anderson (1947), in Boston, on the average annual increment of normal children in the leg epiphyses, made by measuring the annual movement of the metal marker away from the epiphysis, gave growth charts from which the expected growth to come could be estimated.

Fig. 4.—The interesting appearance in the pelvis and hips of a child who in successive winters was given phosphorated cod-liver oil. (*Reproduced by kind permission from 'The Organization of Bones'* (*P. Lacroix*).)

Finally, this control of growth can be used as a means of correcting deformities. Knock-knees can be corrected by stapling the inside of the knee epiphysial plates, leaving the outer side to grow; 5 in. of knock-knee can be

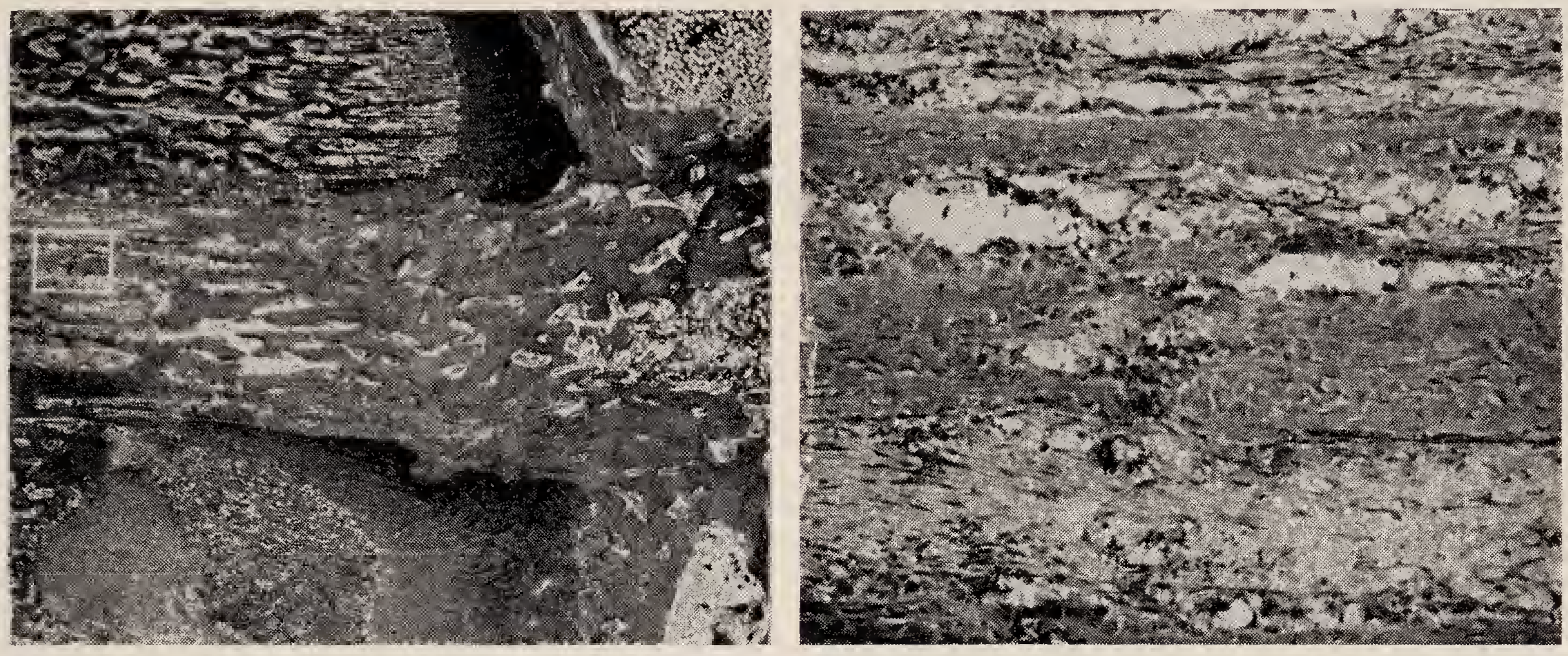
thus corrected in a year. The staples are then removed and the leg continues to grow straight.

There is, however, another facet of bone growth, for some children mature early and others late and how is one to know what growth remains? It has been found possible to estimate the skeletal age as opposed to chronological age by comparing a child's wrist X-ray with certain standard X-rays formulated from the average skeletal development of many normal children.

An alternative method of leg equalization is actually to divide the bone and draw it apart mechanically and slowly until some 2 in. of lengthening is obtained; this takes about a month. The gap then fills in with new bone which grows from the periosteal cells, the periosteum elongating with the slow stretching. If the periosteal tube across the gap breaks, the bone will not unite.

Earlier, it was made clear that longitudinal growth except at the epiphysis did not occur. There are a few situations, however, in which it appears as though there might be growth. In spinal fusion in a growing child where several vertebrae are grafted together, there is some evidence that the graft grows, seemingly stretched by the epiphysial growth of the vertebral bodies which it is attempting to hold together, although, of course, the graft itself has no epiphysis.

Recently, Johnson and Southwick (1960), by an ingenious experiment in rabbits, showed how this might occur. They placed a graft through the middle of the epiphysis, the epiphysial growth plate, and into the diaphysis, and waited for it to join both the epiphysis and diaphysis, thus straddling the epiphysial growth plate with a solid graft. It was found that in some the cartilaginous epiphysis seemed to continue growing, and that in those with the graft fused to bone on either side of the epiphysial plate, growth must lengthen the graft. In others it became narrow and degenerate. On careful study there were found occasional trabeculae which seem to have given way (*Fig.* 5). Their concept is that if the growth force is strong enough trabeculae can be stretched; they then lose continuity, elongate, and rejoin solidly with bone. This process goes on continuously and thus allows a graft to lengthen; each trabecula is stretched, breaks, lengthens, and reunites. This is, of course, not in any sense a normal form of bone growth.



A B

Fig. 5.—A, The fibular graft across the epiphysial growth plate. B, The squared section is shown at higher power, and it is possible to see a break in the trabecula which it is believed has been stretched and thus broken. It will later reunite, elongated. (*Reproduced by kind permission from the article by J. T. H. Johnson and W. O. Southwick in the 'American Journal of Bone and Joint Surgery', December*, 1960.)

Bones obviously grow in width as they do in length. Many years ago it was noticed that if pigs ate madder the new bone formed during the period of madder feeding was stained pink

(Belchier, 1738). From such observations it became obvious that bone could be derived from the periosteum. When a bone grows wider it enlarges by this new periosteal bone, but, also at the same time, the medullary canal

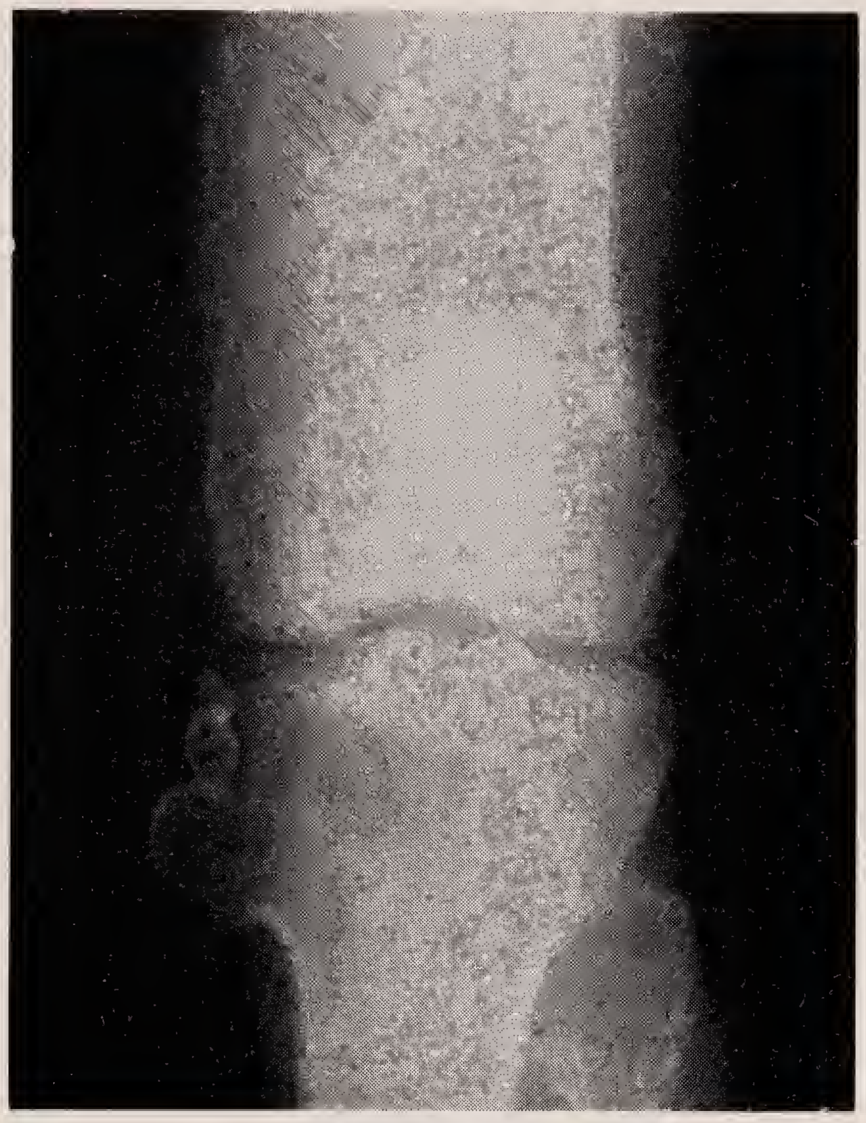


Fig. 6.—Ollier's disease showing the failure of tubulation of the ends of the tibia and femur. Often associated are the exostoses as seen.

widens by absorption of the innermost bone. As growth proceeds, all the diaphysial bone laid down originally at the epiphysis is removed in the growth of the medullary canal. There has now been a complete removal of all bone, both that formed in the embryo and by the epiphysial plate and its substitution by periosteal bone, the former developed from cartilage, the latter by intramembranous ossification. An interesting confirmation of the osteogenic role of the periosteum is seen in scurvy of infants. In this disease bleeding occurs easily, stripping off the periosteum, which then proceeds to lay down bone.

The ends of the long bones are always wider than the shaft. The upper end of the tibia is an excellent example; the shaft below is narrow and yet the epiphysis from which it was formed is much wider than the widest part of the shaft. This means that the ends are narrowed by absorption as the epiphysial plate grows away. This process of modelling is known as tubulation, and in a condition known as Ollier's disease (*Fig.* 6) tubulation fails, and so the bone ends have elongated, wide extremities; similarly in osteopetrosis. In the condition of diaphysial aclasis, multiple exostoses grow near the epiphyses. It seems likely that cartilage cells from the epiphysial plate tethered to the periosteum are pulled down as the periosteum grows; but still having growth potential, they go on developing and produce bony exostoses. This abnormality is an inherited one implying a chromosomal abnormality.

It is a fascinating problem to consider the mechanism by which the insertions of muscles and ligaments stay in the same relative position to the bone throughout the complex growth changes which take place. One explanation is that many of these insertions are into the periosteum and not fixed to bone, at least during growth. The periosteum is attached to the two epiphyses and appears to behave rather like a sheet of elastic. Thus, although one epiphysial cartilage plate may grow more rapidly than the other, the periosteum, being stretched between the two, moves over the underlying bone, and insertions of ligaments and tendons will move with it. The effect of this would be that in general these attachments would tend to be displaced in the direction of the growing epiphysial cartilage plate, whereas if they were fixed to bone the plate would constantly be leaving them behind. They are rather like ships which drag their anchor but stay the same distance from the shore.

In a rare disease, melorheostosis, the periosteal bone is laid down as a thick, dense, irregular mass; it is sometimes known as 'candle-grease disease'.

The earliest bone which is formed is haphazard in its arrangement and is known as woven bone. The bone which replaces it during the remodelling processes, which in man commence in utero, is lamellar in character, an arrangement which confers greater strength.

Within the first year of life the lamellated bone begins to show organization into units of structure which are an important contribution to the remarkable strength of bone. Within cortical bone these units, known as osteons, consist of concentric lamellae surrounding a vascular canal and orientated so that their long axes correspond in general to the long axis of the bone. In cancellous bone, also, the individual trabeculae show an arrangement which is determined by the lines of stress to which the bone is subjected.

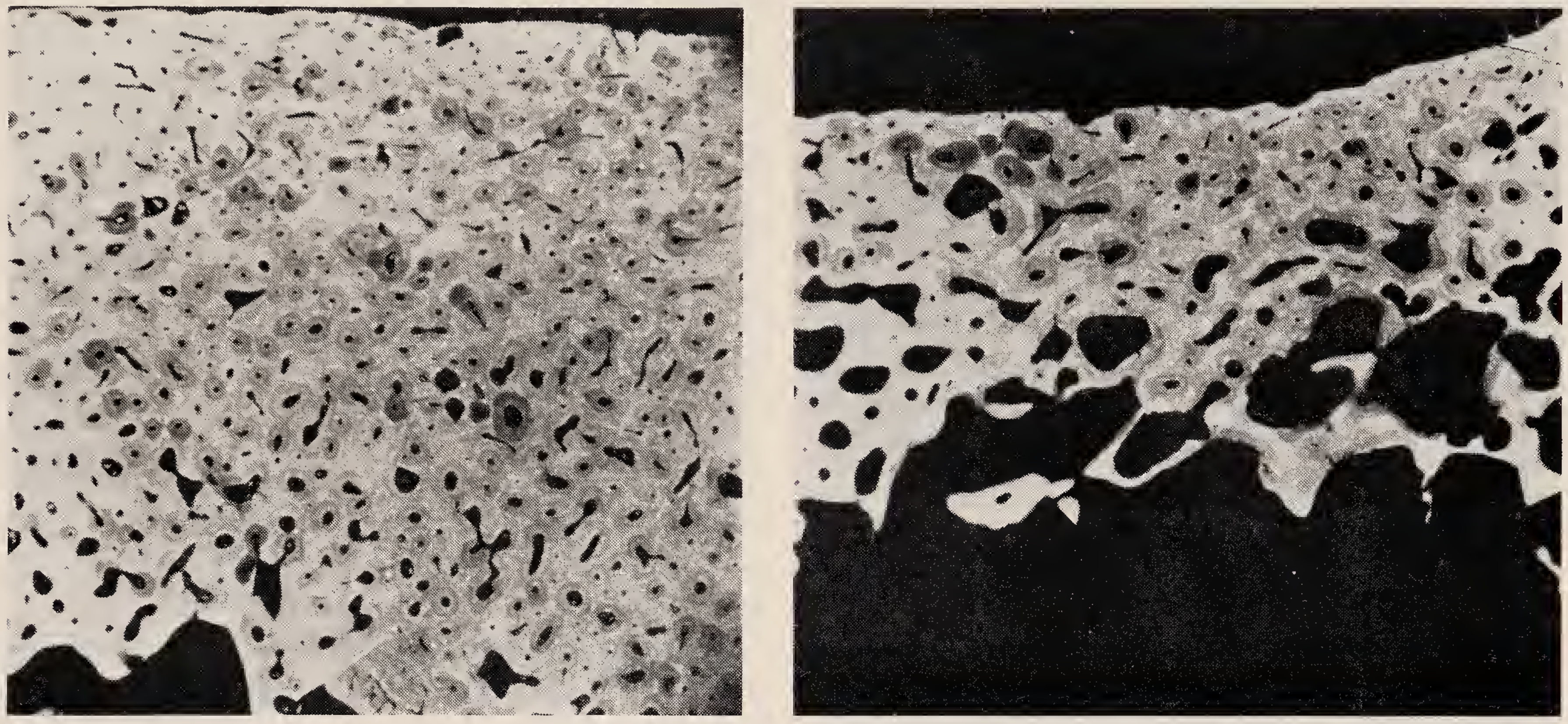


Fig. 7.—Osteoporosis. On the left is demonstrated normal bone and on the right osteoporotic bone. The bone is normal in quality, but diminished in quantity in osteoporosis.

It is now appropriate to discuss certain aspects of the constant changes that go on in bone throughout adult life. In one respect this is perhaps not true growth, but it is the normal physiological change in the maturing of bone and is of the greatest interest.

Bone has three main constituents; the mineral content, the binding fibres of collagen, and the ground substance in between containing much mucopolysaccharide. Plasticity of bone was to be the theme of this discourse; much of orthodontic work would be impossible if it were not.

Recent studies of the formation and absorption of bone with the aid of isotopes and of tetracycline-stained bone have advanced our knowledge considerably, although the mechanism of control is still ill-understood. However, when one ponders on what might effect these changes one can comprehend certain facts and factors.

Firstly, the raw material must be there, and in diets with a lack of calcium or protein there is a deficiency of bone formation. In gross form this may cause osteomalacia. In old age when removal of bone exceeds formation osteoporosis develops. In osteoporosis there is an abnormally small quantity of normal bone, but there is no change in the quality of the remaining bone (*Fig.* 7).

The effect of vitamin-D deficiency on the growing bone has already been discussed. In the adult also it can cause changes in bone which are called osteomalacia, a disease characterized by inadequate mineralization of newly formed bone matrix or osteoid in which the amount of bone formed is normal but the quality is poor because it is deficient in mineral. Vitamin D assists mineralization of bone by facilitating the absorption of calcium from the gut and by increasing the resorption of phosphate by the kidneys—both being major constituents of bone mineral. Dietary deficiency of vitamin D is uncommon in this country, but malabsorption of this vitamin is a feature of many diseases and sometimes arises following operations to remove most of

the stomach, which was the aetiology of osteomalacia shown in *Fig.* 8, showing the development of spontaneous fractures as a result of bone softening.

Parathormone, the secretion of the parathyroid, is now well known to be the most

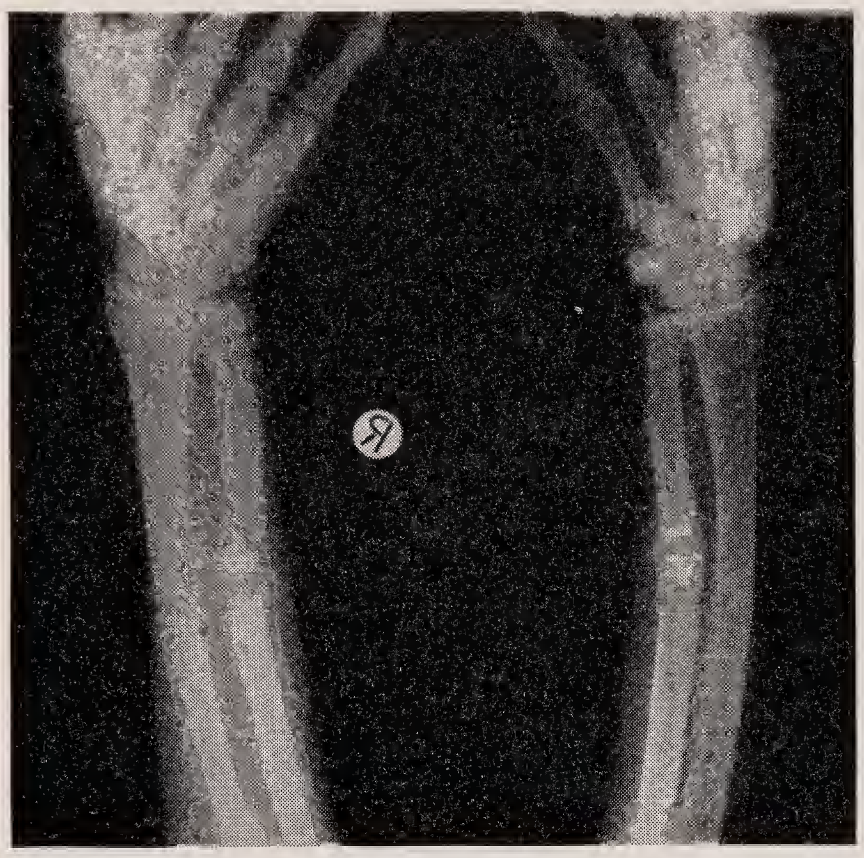


Fig. 8.—Osteomalacia following partial removal of the stomach. The fracture in the ulna is known as a pseudofracture and is due to weakening of the bone from malabsorption of calcium and possibly vitamin D.

important general controlling factor, an excess of it favouring destruction or absorption of bone to increase the level of blood-calcium, the level in the blood controlling the secretion of parathormone itself.

If calcification is to be normal, there must be a collagen framework. Collagen is protein and under certain conditions its formation is defective. It may be an inherited deficiency, as in fragilitas ossium. In this disease the bones lack collagen, as do all connective tissues. For this reason one can see the blue of the retina through the wall of the eyeball capsule.

Osteoporosis may be local, such as occurs when a limb is immobilized following injury, or generalized in a number of systemic disorders affecting the skeleton. By far the most important of these, clinically and socially, is the condition of senile osteoporosis, an exaggeration of the inevitable atrophy of the skeleton which accompanies age; it is a frequent cause of fracture. This type of osteoporosis occurs most commonly in postmenopausal women, and the reduction in circulating oestrogen is thought by some to be an aetiological factor. Others believe that a low calcium intake is the more important cause.

Although common, we are not sure how common, for minor degrees are impossible to detect and probably at least 50 per cent of the skeleton must disappear before there is the slightest evidence of osteoporosis in an X-ray of the bones. Reliable methods of comparing the density of bone in X-ray have so far not become available. The incidence is the subject of a most intensive investigation, for this is now one of our major problems.

Such changes of bone are under the control of many other factors than those so far discussed; in addition to the parathyroid the pituitary and thyroid hormones and the hormones derived from the testicle and ovary play a role, though less significant than the parathyroid.

The factors so far discussed are general, but local conditions are of immense importance. Wolfe's law has been variously phrased, but it may be expressed as: 'Bone is laid down where it is needed and removed where unnecessary.'

One of the best illustrations known to all of us is the trabecular pattern of the femoral neck. When one looks at a section of the femoral neck the bone structure is such that the maximum support is provided. The trabeculae are arched to bear the very large stresses that are transmitted and from the engineering point of view their architecture is perfect; it is very evidently that which combines strength with lightness. Although the femoral neck is the most easily demonstrated example of this, all weight-bearing bones show the same adaptation.

The mechanism by which this is effected is quite unknown to us. By some means the osteoblast is induced to lay down bone where the greatest stresses are felt and the osteoclast excited to remove what is not needed. It is suggested that these two types of cells have

some ability to act as strain gauges, but how is not even surmised.

This change of trabecular pattern is in no sense inherent. If a bone is fractured and heals with some malposition, within one to two years the trabecular pattern is re-established along the new lines of stress. The continuous remodelling which may occur after fractures is well known. This ability to change is again evident.

In deformities of bones which are long-standing we see many adaptations to new position and new lines of weight-bearing. In curvature of the spine the vertebrae are decreased in size on the concave side. This failure to grow on the concave side and to be rotated into the deformity is secondary to the deformity, not the cause of it. In other words, the bone has been moulded by whatever causes the deformity, which in some instances may be a muscle imbalance, as after poliomyelitis, where muscle pull can have an astonishing deforming effect on growing bone (*Fig.* 9).

An example of external pressure causing a bone to change is well seen in the Milwaukee brace. This jacket is designed to stretch the child and remove the effect of gravity, which it most effectively does in the treatment of scoliosis. However, the pressure on the jaw may cause the teeth to protrude with necessarily changes of form in the jaw. When the pressure is removed many of these teeth spontaneously revert to their normal position. Your President, Dr. Logan, has investigated these problems, and amongst other things has developed a most ingenious method of continuously recording the pressure on the mandible from the brace.

As is well known, continuous or intermittent pressure on bone can cause change of shape and absorption. Thus an aneurysm of the aorta causes absorption of adjacent vertebrae. Pressure from incompletely fixed pins in fractures or artificial hip-joints can cause bone absorption by slow cellular removal from intermittent pressure of metal on bone.

When a bone-graft is inserted, or a piece of bone dies within the body, an interesting form of bone growth occurs. The cells of the bone-graft all die just as they would have done in avascular necrosis following injury. Initially, a dead piece of bone appears to become dense in X-ray, in fact it remains of the same density; for it is outside the circulation

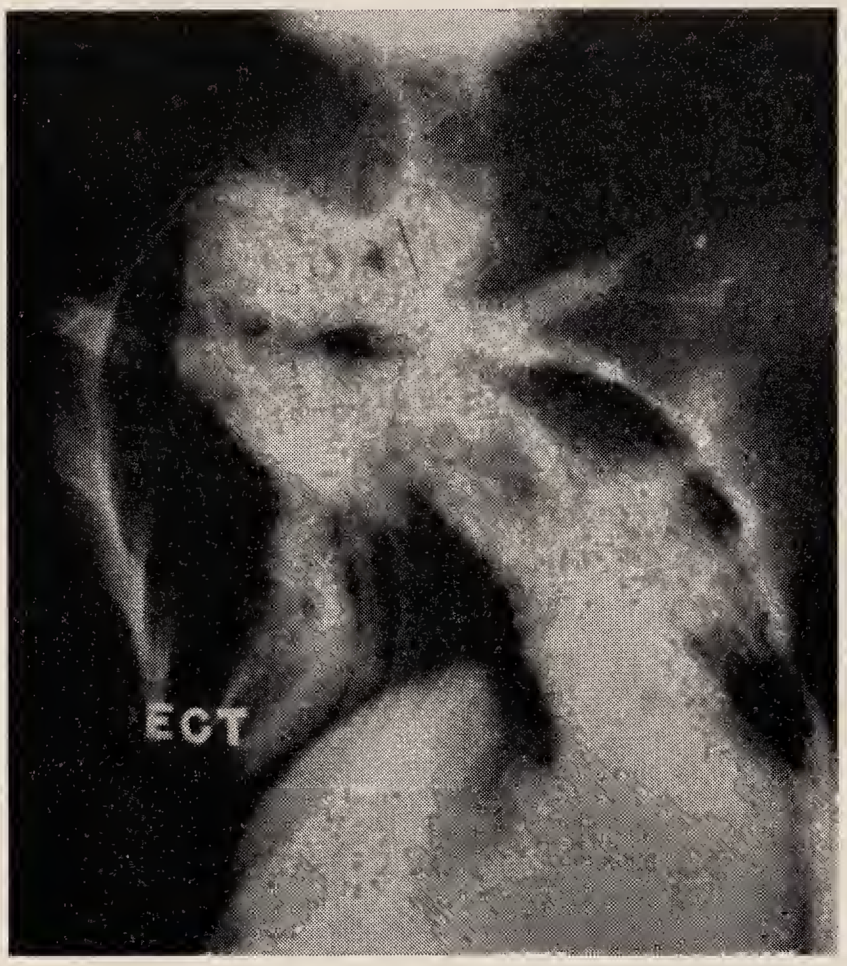


Fig. 9.—The extraordinary effect that unbalanced muscle pull can have in deforming growing bone. This boy developed poliomyelitis and had weakness of the intercostals on the convex side. Thus the spine was pulled over by the stronger intercostals and developed this tremendous curvature in a period of three years.

and cannot be altered. The surrounding bones, however, undergo disuse atrophy and become rarefied, causing the dead bone to show up as though denser in comparison.

Over some months or years this bone radiologically appears to break up and then slowly to become normal in density and pattern. Histologically, this is seen to be a process of creeping substitution. Capillaries grow into the dead bone from surrounding vascular tissue and following this, and apparently using the dead bone as a scaffold, living bone grows into and extends throughout the dead bone. At the same time osteoclasts effect a progressive resorption of the dead bone and remodel the living bone until there is an eventual total replacement of the dead by living bone of normal structural arrangement.

This now leads almost to the last aspect of bone growth for discussion, which is to indicate how a fracture heals, a process which is necessarily the growing of bones across a gap.

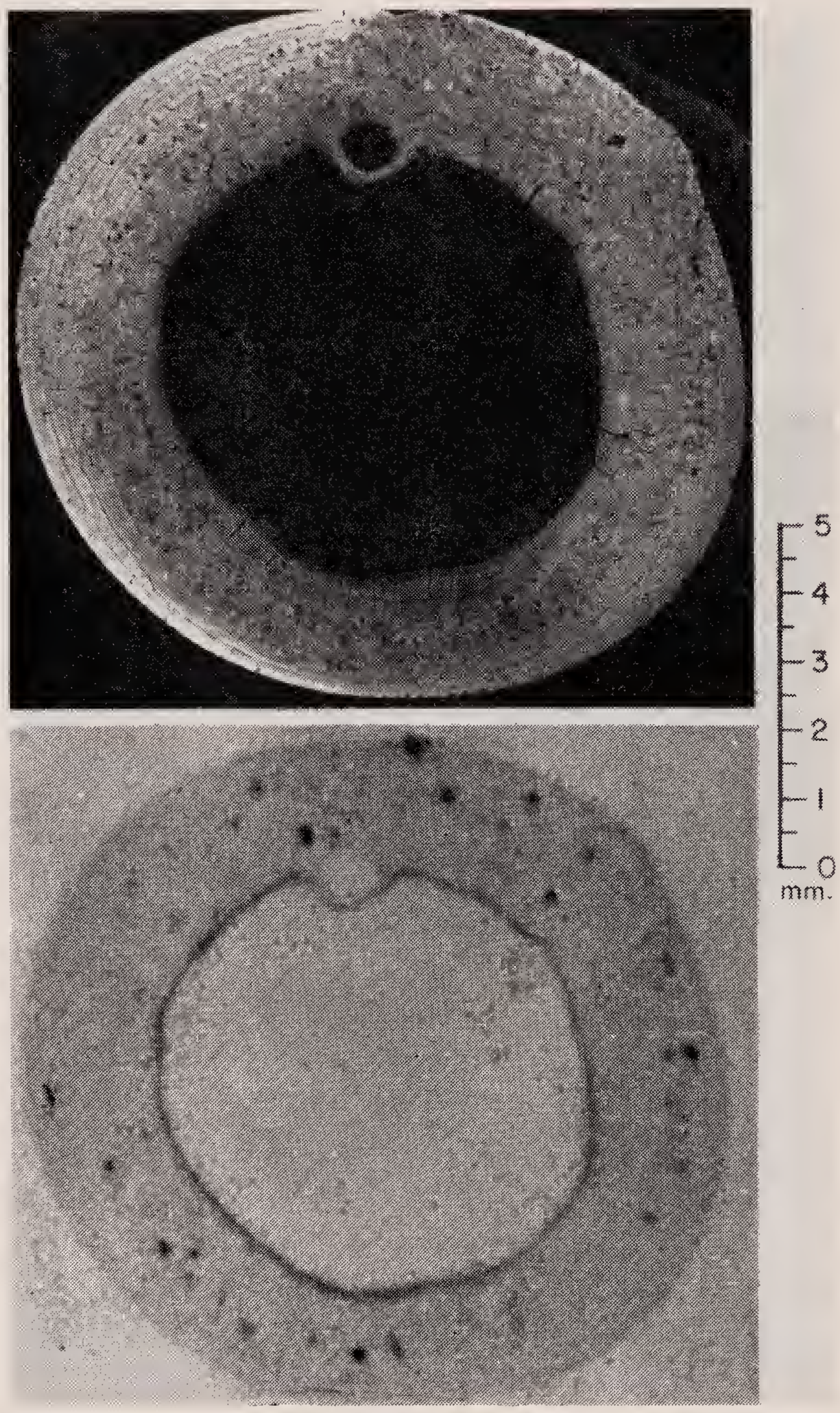


Fig. 10.—Corresponding micro- and autoradiographic cross-sections of the femur of an adult dog labelled with Ca^{45} two weeks previously. Notice the 'hot spots' which are localized, but show bone activity in the adult. (*Reproduced by kind permission from 'Radiation Research'*, 1959, **10**, 213.)

The healing of bone is very like any other tissue. The haematoma is encircled by a vascular granulation tissue, and this prepares the way for new bone arising from the surface of the fractured ends to extend across the gap. This new bone has the structure of woven bone and is therefore mechanically unsound, but in the subsequent remodelling it is replaced by lamellar bone with normal architecture. At the time this late reconstruction is going on, excess callus is removed both externally and within the medulla, and in two to three years' time the broken bone has grown into normal bone again.

Our very last discussion centres on the histological and chemical changes which go on in bones absorbed and replaced in the many processes discussed. It is proposed to outline briefly how the newer methods of investigation by isotope and tetracycline markers are utilized and what one may expect from this research in the next few years.

It has been known for many years that certain radioactive elements were 'bone-seeking', that is, they are taken up in the bone crystals in the same way as calcium. This was first recognized among watch-dial painters accidentally poisoned by radium-containing paint and subsequently developing malignant disease in their skeleton (Martland, 1931). The danger of bone-seeking isotopes with a long half-life such as radium or that product of a 'dirty' atomic bomb, strontium 90, is that although the total intake may be small they tend to become concentrated in those parts of the skeleton where new bone formation is taking place, giving rise to 'hot spots' in the vicinity of which a dangerous level of irradiation may develop (*Fig.* 10) (Looney, 1956).

This tendency for bone-seeking isotopes to be taken up at sites of new bone formation has enabled the identification of these areas in experimental work. From studies such as these it has been possible to show that mineralization proceeds rapidly in a developing osteon, and that there is also a slight diffuse uptake in mature bone—possibly as a result of ion exchange at the surface of the bone crystal. Yet another isotope, yttrium 90, is taken up at sites of bone resorption, enabling them to be identified (Jowsey, Sissons, and Vaughan, 1956).

Clinically, use has been made of bone-seeking isotopes. For example, by injecting an isotope with a short half-life and measuring its rate of clearance from the blood, making suitable correction for loss in faeces and urine, it is possible to arrive at an estimate of the

overall rate of bone formation. This has been made use of to differentiate various metabolic diseases of bone (Meltzer, Lyon, Mensen, and Ray, 1960). Also, by external counting over a diseased bone and comparing this with the activity of the opposite normal limb, it is possible to learn about the metabolic activity of the abnormal bone (Bauer and Wendeberg, 1959).

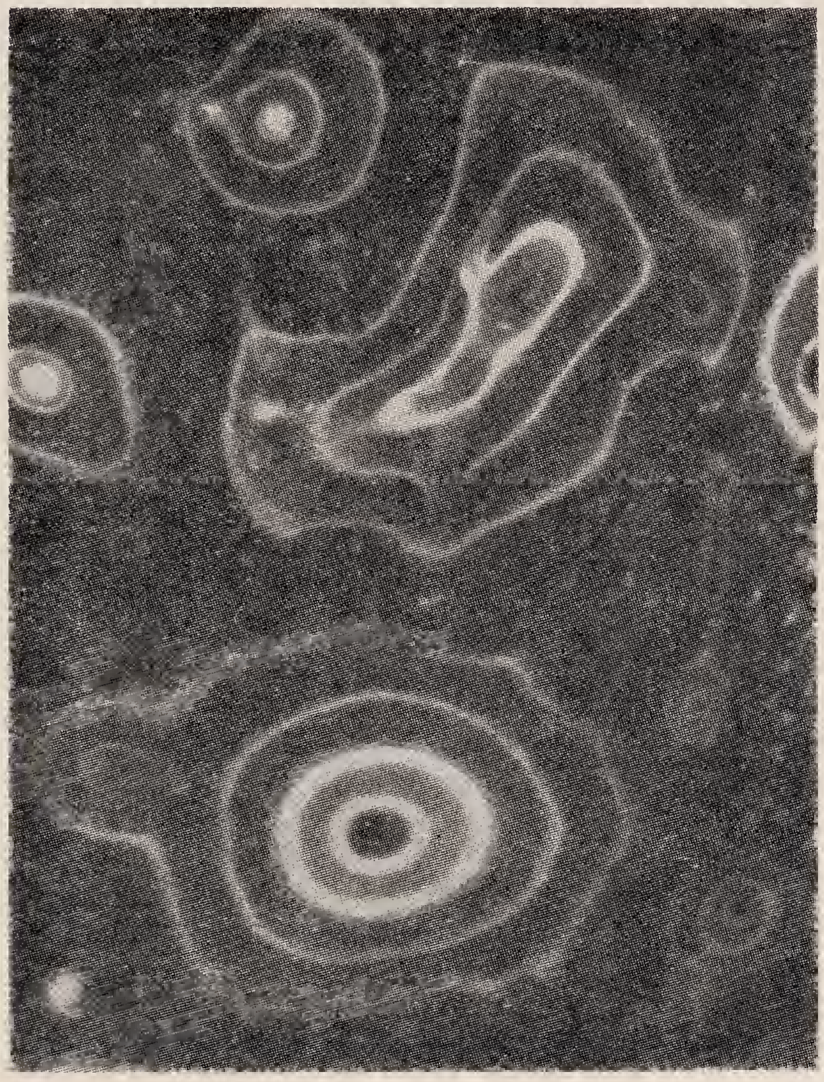


Fig. 11.—In a growing dog tetracycline was given on four separate occasions at intervals. The tetracycline was taken up and shows as fluorescent lines and demonstrates beautifully the growth activity in the Haversian systems. (*Reproduced by kind permission from the article by W. H. Harris in 'Nature, Lond.', December*, 1960.)

Another recent development which has contributed greatly to our knowledge of normal and abnormal bone growth has been the discovery that the tetracycline group of antibiotic drugs are taken up at sites of new bone formation and may subsequently be recognized by their property of fluorescence (Milch, Rall, Tobie, Albrecht, and Triviers, 1958).

Just as madder-staining of bone has contributed much information on the grosser aspects of bone formation so the tetracyclines have yielded information on bone growth at a microscopic level. Cortical bone from a dog, which has been labelled by tetracycline at known time intervals, shows the rings of fluorescence corresponding to the bone formed during the labelling period (*Fig.* 11) (Harris, 1960). By measuring the amount of bone deposited between the rings it is possible to estimate the rate of bone formation within the osteon. This principle has been made use of in the study of bone growth in health and disease (Frost, 1961).

It never ceases to be surprising how active a tissue even adult bone is and even now how little is known about it. If this review has demonstrated that bone can and does change, and gives some insight into our present knowledge of how it is done, its purpose will have been served.

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DISCUSSION

Dr. J. R. E. Mills said that there were three points which had occurred to him. The first concerned the statement that the long bone which was completely immobilized did not grow to its full length, but failed to do so by several inches. At one time it was firmly believed that if a person did not chew his food so many times he would have small jaws. What did Professor James consider to be the minimum amount of function necessary to achieve full growth?

As to the elongation of bone, could they be told what happened to the muscle? Did the muscle attachments change or did the muscle elongate as necessary?

The third point related to the effect of environment on the shape of the bone. They had heard about the child with unbalanced muscle action, and everyone knew of the stock example of the binding of the feet of Chinese women which produced feet that were deformed. It appeared that any force which was going to alter the shape of the jaws would have to act on the jaws almost all the time and with a pressure which would damage soft tissues.

Professor James said that, in arrest of the epiphysial plates due to immobilization, it was important to make it clear that it was the epiphysial plate that was affected. After 18 months of immobilization there was a danger of central perforation of the plate with bony fusion across it. So far as he knew, there were no other factors than continued immobilization and disuse.

In relation to leg lengthening as had been described, and the question of what happened to the muscles, there obviously must be stretching and lengthening, and this presented many of the technical problems of the method. It should be remembered, however, that most of the legs that were lengthened were paralysed and the muscles were easily stretched. A common example was a paralysed leg, following poliomyelitis, which had not grown because of lack of muscles in the leg. If a leg with good muscles or partially good muscles were lengthened it might be found that the balance of muscles was upset. When the tibia was stretched, a calf muscle might cause a deformity by not stretching as much as the shin muscles. Muscles and nerves had to be lengthened without damage being done to either. Over a month 2 in. of lengthening can be safely, but slowly, obtained.

The question of the environmental factors affecting bone was something about which they knew more than he did—and perhaps none of them knew very much. There was no doubt that bones, even solid bones, could be altered by muscle pull. It was very difficult to alter bones by external means. Splints had been used in cases of knock-knee. Only part of the deformity was in the bone, and even here splintage had virtually been given up. External pressure on bones as a method of correcting deformity was almost valueless. Such a long and continuous pressure must necessarily damage the soft tissues through which it pressed.

Mr. J. S. Beresford said that a reference was made to muscles affecting the growth of bone. Could it be said how the failing of a muscle could affect a bone?

Professor James said that the most obvious situation known to him where muscle paralysis affected the growth of bone was in poliomyelitis. The failure to grow was thought to be due to a decrease in blood-supply because of lack of use of the limb and of muscles which were attached to the bone and which increased the blood-supply to the bone. The amount of shortening that might arise in a paralysed leg was roughly proportionate to the amount of muscle paralysis. There were exceptions. He once saw a boy with a totally paralysed leg which was 1 in. longer than the normal leg, but usually 1, 2, or 3 in. shortening was seen in the paralysed leg.

Mr. L. H. Russell said he wished to ask a question concerning tetracycline labelling. How soon was it taken up into the bone and was it ever eliminated?

Professor James replied that it was eliminated, but he was not sure how long it took. The question of absorption had not been studied specially, but the time taken for it was very short.

The President asked whether there was any explanation for the undoubted malleability of part of the bone surrounding teeth compared with the basal part of the same bone. In scoliosis cases he did not recall seeing any change in the actual shape of the mandible.

Professor James said that spongy bone was easily altered even if it had a thin cortex in front of it. A hard bone such as the femur was very difficult to alter, and yet if a benign tumour grew against the femur for a number of years an indentation would be seen. As the tumour grew it absorbed the bone and might come to lie entirely within the cavity of the bone, but that would take many years. That was presumably a pressure atrophy interfering with the blood-supply. It was a subject about which very little was known.

The President asked whether experience could be quoted which would lead them to believe that the shape of the growing mandible could be altered by pressure. Could they alter its length or obtain some effeet on the growing condyle?

Professor James answered that the force needed to alter the shape of a bone would be formidable.

Mr. D. T. Hartley wished to know whether it could be said that if a mandible were immobilized its growth would be reduced; and, if so, how long would it take to have a measurable clinical effect?

Professor James replied that he could say what happened only in the case of legs. When they were immobilized upwards to a year and a half there was no effect on their growing; and then, not so much because they were immobilized, but because the epiphysis gave way, the growth stopped.

Mr. A. J. Walpole Day asked whether Professor James believed that pressure on the mandible could deform it so that, instead of being rather long, it was rather square.

Professor James said that natural conditions which were found, such as abnormal muscle pull, were so long continued that it was difficult to imagine a mechanical device which could have the same effect with regard to a bone.

Mr. Walpole Day interjected to say that he was thinking of a growing bone.

Professor James said that, even so, he believed it would still be difficult in relation to a whole bone. No experience in orthopaedics was known to him where the whole shape of a growing bone had been altered.

Mr. D. F. Glass asked whether, in a bone-graft, it was assumed that all the bone in the graft was absorbed and then replaced by the surrounding bone. Also, if a bone-graft were carried out on a weight-bearing bone, at what stage would one allow the bone to bear weight again?

Professor James replied that if a patient was given a bone-graft from somebody else the cellular structure died; if a bone-graft was taken from the patient himself it was possible, but probably unimportant, that a certain number of the periosteal cells survived. The bone itself, apart from these cells, died. It was then invaded by the vascular tissue; osteoclasts removed the dead bone and new bone was laid down immediately afterwards by the osteoblasts. Thus the graft was removed and replaced.

It was difficult to know what a bone-graft did and what part of a bone-graft was important. The cells were known to be unimportant. One could boil a bone and rid it of all the organic materials, or most of them, and it would still act as a graft, though admittedly not as constantly. A bone that was decalcified would still act. Every constituent part could be separately taken away and it would still act as a bone-graft.

There was some suggestion, without much evidence, that bone had a chemical osteogenic effect. However, when bone was implanted it seemed to have an osteogenic effect and acted as a guiding channel for the vascular loops to grow in to replace the bone. In recent years there had been a change from graft using cortical bone from the tibia to the use of cancellous bone from the ilium. The vascular tissues could invade and replace it within 3 months, whereas the time with hard bone might be 6 months or a year. One patient who was grafted with tibia 20 years before was re-operated upon and the middle of the graft was still found to be dead.

The answer to the question when weight-bearing on the bone was allowed was the same answer as that given to the student who asked how long a fracture of the tibia was immobilized; until it was united!

Mr. D. T. Hartley asked to what extent the speaker's findings on long bones might be applied to the mandible.

Professor James said that there was hardly any difference between one bone and another except in points of detail, and he could not see why the general principles discussed that evening about bone growth should be different from those for the mandible.

A ROENTGENOGRAPHIC CEPHALOMETRIC ANALYSIS OF TREATMENT AND GROWTH CHANGES IN A SERIES OF CASES OF MESIOCLUSION

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REVIEW OF LITERATURE

The roentgenographic cephalometric analysis of changes following treatment in cases of mesioclusion has received little attention. Brodie, Downs, Goldstein, and Myer (1938) included a few cases of Class III in their paper concerned with all classes of malocclusion. Apart from references to individual cases in growth studies, such as those of Bjork (1951) and Donovan (1953) and some illustrative cases in a paper by McCallin (1955), no further review of treatment or growth changes in a series of Class III cases appeared until the paper by Braccessi and Lucchese (1958) on the skeletal and dental changes in 30 treated cases of Class III malocclusion aged 8–12 years. They found successful treatment depended on a favourable pattern of growth. Gugny (1959) stressed the dominance of growth rather than the effect of appliance therapy in a report on 2 cases, Parker (1960) and Gould (1960) have each described changes in a single case, and Blyth (1959) has described what he terms 'failure of vertical development' in some treated cases of Class III.

MATERIAL

The material consisted of serial roentgenographic cephalometric records, dental record casts, and full-face and profile photographs of 139 cases of mesioclusion. Nine cases judged untreatable by orthodontic means were referred for surgical correction. The remainder were divided into groups based on the stage of the dentition at the first examination and comprised:—

Deciduous dentition	14
Mixed dentition	96
Permanent dentition	20
	130

METHODS OF TREATMENT

In the majority of cases appliance treatment was used with the primary aim of correcting the incisal relationship, but in a few cases observation only was thought necessary. The method of treatment was mainly by removable appliances; other forms of treatment included functional appliances, occipital traction by means of a chin cap and head gear, and intermaxillary traction by fixed appliances. Abbreviations used in the text and the tables to designate the type of appliance used in a particular case are as follows:—

AP. Ex., anteroposterior expansion using a Johnson twin wire arch with coil springs on the buccal tubes.
C.L.I.P., cast lower incline plane cemented on to the lower incisors and canines.
Funct., functional appliance of reverse Andresen (R.A.) or Bimler type.
L.R.A., lower removable appliance to retract the lower incisors with molar capping to open the bite.
O.M.T., occipitomental traction—occipital traction plus forward traction on the maxilla by elastic bands attached to posts on the chin cap.
O.T., occipital traction—backward traction on the mandible with elastic traction from a chin cap to a head cap.
R.I.M.T., reverse intermaxillary traction by means of fixed appliances.
T.W.A., Johnson twin wire arch.
U.R.A., upper removable appliances with finger springs, screws, or rubber pegs to proclinate the upper incisors, the bite being opened to unlock the incisor bite by molar capping.

METHODS OF ANALYSIS

Methods of Superimposition.—The serial tracings were superimposed on De Coster's line and the SN line of the first tracing was transferred to subsequent tracings and called the cranial base reference line. Nasion was not used as an end point in the serial tracings because of its variability in a vertical plane, as has been described elsewhere (Hopkin, 1962). The cranial base reference line is in the same relationship to the cranial base in

Given at the meeting held on 10 Dec., 1962.

all the tracings. Where the anterior end of the line did not pass through nasion its point of intersection with the frontal bone was used as nasion for angular measurements involving this point. The lines representing the axial inclinations of the upper and lower incisors were transferred from the first to subsequent tracings of the same individual by superimposing upon the outlines of the incisors.

Angular Changes Measured.—The principal angles studied before and after treatment are illustrated in *Fig.* 1 and are listed below, together with the abbreviations used to indicate them in the tables of angular changes.

U.I., angle of upper incisor to cranial base reference line.
L.I., angle of lower incisor to mandibular plane.
A/B. diff., the difference between ∠SNA and ∠SNB.
Y.Ax., the Y axis (∠NSGn).
O.P., the angle of the occlusal plane (Bjork-tip of $\underline{1}$ to tip distal cusp $\underline{6}$) to the cranial base reference line.
Mn.P., the angle of the mandibular plane to the cranial base reference line.
Mn.∠, the mandibular angle (∠ArGoGn).
Mx.P., angle of the maxillary plane to the cranial base reference line.
∠Con., complement of ∠NaPo. (+ if A in front of Po, — if behind)

The records of angular changes in individual cases have been recorded elsewhere (Hopkin, 1961), and in the tables the mean changes only in the various groups of cases are given.

Assessment of Changes due to Growth.—The direction and amount of growth in each case were assessed by superimposing the successive tracings on the cranial base line to observe the general direction and the amount of growth, followed by individual superimposition of the maxillary and mandibular outlines, using the maxillary plane with PNS registered, and a plane tangent to the lower border of the mandible and the angle, passing through menton, with Gn registered. It is not practicable to describe in detail the growth changes in each of the recorded cases, apart from cases of special interest, and an average picture only of the material as a whole can be given. The amount and direction of change were not measured, and are described in general terms.

FINDINGS

It has been shown elsewhere that reductions in the linear and angular dimensions of the cranial base are primary factors associated with mesioclusion (Hopkin, 1961). It is not to be expected that the application of corrective forces to the dento-alveolar structures will modify those of the cranial base. Theoretically, the most that can be expected is a

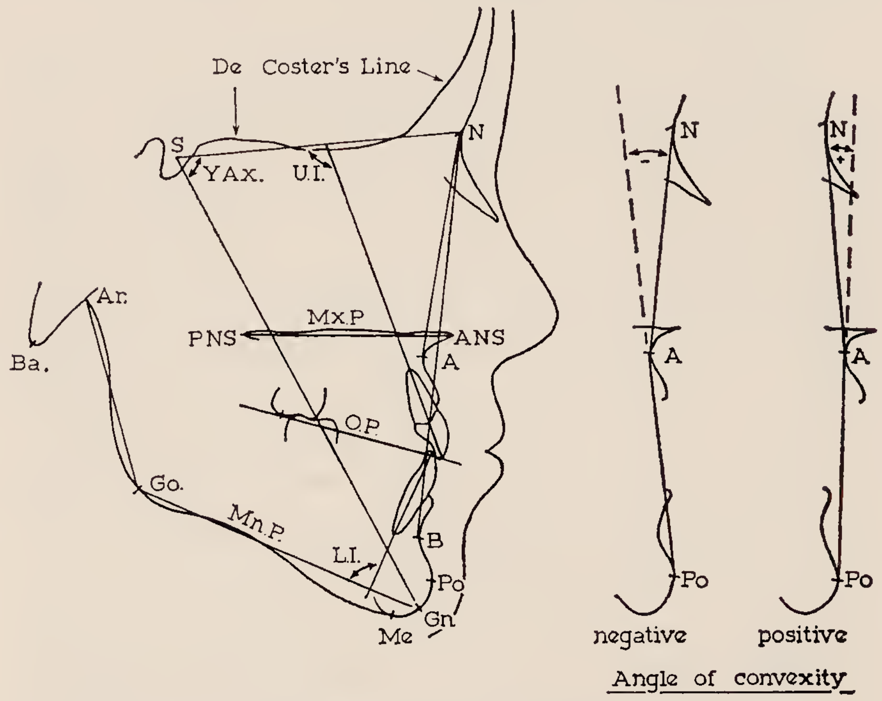

Fig. 1.—Points, planes, and angles used in cephalometric analysis.

modification of the adverse ratio of mandibular to maxillary growth sufficient to permit stable, normal, incisal occlusal relationships. Whether or not orthodontic treatment is able to alter or modify the inherent pattern of jaw growth is an extremely controversial question, and the findings in this study do not support the positive view. It will be shown that the primary effects of orthodontic treatment are limited to the teeth and alveolar bone, but that secondary effects on mandibular position do also occur consequent upon the corrected incisal relationships. Further, it will be shown that the growth patterns of the maxilla and mandible are not only unaltered by treatment, but also that they determine the success or failure of treatment and the long-term stability or relapse of the treated cases. The findings are considered under three main headings: (1) Treatment and growth changes in cases whose treatment was started in the deciduous dentition; (2) Treatment and growth changes in cases whose treatment was started in the mixed or permanent dentition; (3) A comparison of the treatment and growth changes in a series of relapsed cases with those in a series of successfully treated cases.

1. Treatment and Growth Changes in Cases whose Treatment was started in the Deciduous Dentition.—The changes noted in the 14 deciduous dentition cases during and after treatment are considered in two main respects: (*a*) effects of treatment and (*b*) growth and developmental changes.

a. Effects of Treatment.—

i. *Results following Incisal Correction in the Deciduous Dentition.*—The correction of a reverse overjet and overbite in the deciduous dentition had no effect on the occlusion of the permanent incisors. In 5 cases in which incisal correction was obtained by the use of upper removable appliances the permanent incisors erupted into a reverse overjet and overbite.

Discussion: Any effect on the supporting alveolar bone of the incisal proclination is temporary, as this bone is of course resorbed with the shedding of the deciduous tooth, the alveolar bone of the permanent incisor growing up with the newly erupting tooth. Although Ritchie (1960) has reported the correction of lingually occluding deciduous incisors being followed by normal occlusion of the permanent incisors in 2 out of 4 uniovular quadruplets, in the other 2 the permanent incisors erupted into lingual occlusion, and it may well be that the incisors of the treated quadruplets would have shown self-correction, and this is not unknown and has been reported, for instance, by Kantorowicz (1926) and Korkhaus (1934, 1957).

Table I.—Comparison of Linear and Angular Growth Changes in Traction (T.) and Non-traction (NT.) Cases, in Mandibular Length Ar–Gn, Mandibular Angle ∠ArGoGn, and Y Axis ∠NSGn

Case No.	Period under Observation	T./NT.	Ar–Gn	∠ ArGoGn	Y Axis
	yr. mth.				
D.F.4	5 0	T.5 Y.	+16·1	+1·5	+2·5
D.F.5	4 0	T.7 M.	+10·1	−4·0	+3·0
D.M.3*	4 10	T.4 Y.	+10·1	−2·0	+1·5
D.F.1	3 10	NT.	+9·8	−3·0	+2·0
D.M.2	2 8	NT.	+8·1	−2·0	0·0
D.M.4	3 8	NT.	+6·1	−2·0	−1·0
D.M.5	4 5	NT.	+14·2	−2·0	+2·5
D.M.6	3 4	NT.	+9·3	−1·0	+0·5
D.M.8	3 6	NT.	+9·3	+0·5	+1·0
D.M.9	4 3	NT.	+9·0	−1·5	+3·0

* = Occipitomental traction from age 8 to 11 years.

ii. *Results of Head and Chin Cap Treatment.*—This type of appliance, probably first used by Gunnell in 1822 (Weinberger, 1926), was only employed in cases showing a marked reverse overjet. The analysis of the results obtained does not support any claims that its use will restrict mandibular growth, alter mandibular form, or change the direction of mandibular growth. Three patients were treated for 5 years, 4 years, and 7 months respectively by this method. The increases in overall mandibular length (Ar—Gn) and the changes in mandibular angle and the angle of the Y axis were compared with those occurring in the 7 patients who were not so treated; the results are shown in *Table I.* Increases in mandibular length were greater in the occipital traction group than in 6 of the 7 non-traction cases. The 3 traction cases showed an increase in the angle of the Y axis, indicating an increase in the downward rather than the forward vector of growth, but 5 non-traction cases also showed similar increases.

Discussion: Continuous inescapable pressure can distort permanently the shape of a growing bone, as is shown by foot binding and similar practices in the past. Intermittent pressure as applied by the chin cap worn at night can produce local effects on the alveolar bone, as is shown by its successful use by Chapman (1950) and others to retroclinate lower incisors. In order to produce a more general effect, pressure must be applied to the cartilaginous part of the head of the growing condyle and it is doubtful if any pressure from occipital traction does this. Salter and Field (1960) have shown changes varying from superficial necrosis to the loss of the full thickness of an articular cartilage as the result of continuous pressure for a relatively short period. The mandibular cartilage could therefore be expected to show some diminished activity if it were under pressure, which would result in lessened mandibular growth. The evidence presented here does not warrant any generalization, being concerned with only 3 cases, but taken in conjunction with the considerations mentioned above, it is sufficient to raise

doubts as to the value of this method of treatment when used with the aim of modifying the direction or amount of mandibular growth.

b. Growth and Developmental Changes.—The aspccts of growth and development of especial interest in the period covered by the deciduous dentition cases are those concerning (i) the development of the permanent incisor occlusion, (ii) growth changes in the cranial base, and (iii) growth changes in the mandible.

i. *Development of the Permanent Incisor Occlusion.*—It was thought that an explanation of the cases of self-correction quoted earlier could be that the pre-eruptive and eruptive inclinations of the incisors favoured the establishment of normal occlusal relationships, and that conversely in the deciduous dentition cases treated in this series the inclination of the permanent incisors was unfavourable. An examination was made, therefore, of the material from this viewpoint. Records of individual cases are incomplete and the available data for the pre- and posteruptive inclinations of the upper and lower incisors are shown in *Table II.* These figures are compared

Table II.—Axial Inclination in Degrees of Upper and Lower Incisors to the Anterior Cranial Base and Mn. Plane before and after Eruption

Case No.	Upper Incisor Before Eruption	Upper Incisor After Eruption	Lower Incisor Before Eruption	Lower Incisor After Eruption
D.F.1	106·5 95·5	99·0	72·5 73·0	91·0
D.F.4	105·0	105·0	— —	—
D.F.5	111·5	104·5	— 86·5	90·0
D.F.6	100·5	—	— —	—
D.F.7	102·0	111·0	— 111·5	112·5
D.M.2	94·5	89·0	— 77·5	89·0
D.M.3	107·5 104·5	116·0*	— 75·0	89·5
D.M.4	97 100 95	116·0*	79·0 83·0	95·0
D.M.5	108·0 100·0	103·0	— 85·5	88·0
D.M.6	94·0	103·0*	— —	—
D.M.8	86·4	95·0	— —	75·5
D.M.9	98·5 100·5	—	— —	—
DM.10	89·0 90·0	—	79·5 78·5	—

* These cases were under treatment during the eruption of the incisors and some of the increased proclination is a result of treatment.

in *Table III* with the figures for 14 neutroclusion cases and with the figures for 8 cases given by Tulley (1957). A study of *Table III* (A) shows that in the Class III material the upper incisors in most cases were as proclined or more so than those in the neutroclusion or Tulley's sample, and there is no

Table III.—Comparison of Pre-eruptive Axial Inclination of Upper (A) and Lower (B) Incisors in Class III Cases with Neutroclusion Cases and Tulley's Cases. (C) Skeletal Classification of Class III and Neutroclusion Cases in (A)

A	Upper Incisor Inclination between				
	80–90°	90–100°	100–110°	110–120°	120°+
Cl. III	2	3	6	1	—
N.	2	8	2	1	1
Tull.	1	6	2	—	—
B	**Lower Incisor Inclination between**				
	60–70°	70–80°	80–90°	90–100°	100–110°
Cl. III	—	5	3	—	1
N.	—	3	2	3	—
Tull.	1	3	5	—	—
C	**Skeletal Classification of Class III and Neutro Cases in (A).**				
	SkI	SkII	SkIII		
∠SNA-∠SNB	+2° to +4°	+5° and above	2° and less		
Cl. III	1	1	10		
N.	6	7	1		

N.=Neutroclusion. Tull.=Tulley's cases (normal and Class II).

marked difference for the lower incisor inclination between the Class III and the neutroclusion and Tulley's cases (*Table III* (B)).

Section C of *Table III* shows the skeletal classification of the Class III and neutroclusion cases. Apart from one case in Skeletal Class II (*Case* D.F.4), a thyroid-deficient patient who had an atypical skeletal pattern, and one patient in Skeletal Class I, all the Class III cases are Skeletal Class III whilst only one of the neutroclusion cases comes into this class. From this it appears that the anteroposterior relationship of the jaws, rather than the incisal inclination or the effects of deciduous dentition treatment, is the primary factor in determining the initial occlusal relationship of the upper and lower incisors in Class III cases. This is of particular interest in relation to the material examined as the majority of the deciduous dentition cases showed either an edge-to-edge occlusion or a slight reverse overjet of the deciduous incisors, and these are the cases in which an adverse inclination of the permanent incisors could be

expected to be the crucial factor in determining the incisal occlusion. A further observation of interest concerned the inclination of the lower central incisors before and after eruption of the upper central incisors. This was observed in two cases as follows:—

Inclination of $\overline{1}$ before eruption of $\underline{1}$ 89·0° (*Case* D.M.2), 76·5° (*Case* D.M.8).

Inclination of $\overline{1}$ after eruption of $\underline{1}$ 93·5° (*Case* D.M.2), 83·5° (*Case* D.M.8).

After the correction of the incisor relationship in *Case* D.M.8 the lower incisor inclination fell back to 78° without treatment. This spontaneous retroclination of the lower incisor will be shown to be common following correction of the reverse incisal occlusion in the mixed dentition cases.

ii. *Growth Changes in the Cranial Base.*—Observations concerning the growth changes in the cranial base area have been made in a communication elsewhere (Hopkin, 1962), and it is mentioned in this context because the use of De Coster's line is considered to be superior to that of the SN line for the superimposition of serial tracings. Briefly, the evidence put forward showed that whilst changes in the anterior part of the cranial base occurred up to about 7 years or so, after that age the area is comparatively stable. It was also shown that the point nasion may ascend or descend in growth. The use of the SN line for superimposition in such cases has the effect of throwing the profile of the second tracing farther forward where nasion has descended, and where it has risen it throws the profile of the second tracing farther backwards than has actually occurred, and can give rise to erroneous interpretations of growth changes. As De Coster's line has been used for the superimposition line in this study it was considered important to justify its selection.

iii. *Growth Changes in the Mandible.*—The general picture of growth and development in the deciduous dentition cases does not differ from that to be described in more detail for the mixed and permanent dentitions serial studies. Two points of interest about mandibular growth were, however, noted; one was a more constant behaviour of the mandibular angle in the deciduous dentition cases, as compared with that in the older groups, which was more variable. In the 12 cases observed, a reduction in the angle occurred in 10, the average decrease was 1·9° with a range of 1–4°. In 2 cases no change was noted, and there was no case showing an increase. This is too small a sample on which to base a definite conclusion, but the trend shown does agree with the observation of Jensen and Palling (1954) of a continuous decrease in the angle, marked in childhood. The other observation concerned the remodelling of the symphysis at the change from the deciduous to the permanent incisors. This results in a more concave profile of the symphysis, with apparently greater prominence of pogonion to that of point B. This was noted to a greater or lesser degree in 10 of the 11 cases with records covering the change of dentition. This change is brought about by remodelling, and appears to be of a different nature to the increase in the mental prominence to be described in some of the older patients. This latter process seemed to be more in the nature of a localized accretion to the chin rather than of a remodelling of the alveolar profile.

2. Treatment and Growth Changes in Cases where Treatment was started in the Mixed and Permanent Dentition.—The results of treatment in the 116 cases of mesioclusion whose treatment was started in the mixed or permanent dentition are divided into two main groups: 97 'stable' cases and 19 'relapsed and other cases'. The placing of 'stable' in inverted commas is intended to emphasize the point that will emerge in the findings, that the possibility of relapse is always present until growth has ceased. Follow-up records are not complete for some of the so far successful cases in the mixed dentition, and stability cannot yet be claimed with certainty. The 'relapsed and other cases' group includes cases which did not respond to treatment, whose treatment relapsed, or who were under observation only. Individual case histories are not reported, but cases are grouped according to the method of treatment and dentitional group. The angular changes after treatment are described in terms of mean angular changes for each appliance and

dentitional group large enough to justify calculation. The angles considered and appliances used for treatment are indicated by the abbreviations given earlier. It will be seen from *Table IV*, which tabulates the number of cases treated by the various appliances, that the majority of the mixed dentition cases were treated by removable appliances, while the permanent dentition cases were treated mainly by fixed appliances. Details of appliance treatment are not described as the study is of the changes following treatment rather than of methods.

Table IV.—METHODS OF APPLIANCE TREATMENT IN 97 'STABLE' CASES OF MESIOCLUSION

APPLIANCE	U.R.A.	L.R.A.	FUNCT.	C.L.I.P.	T.W.A. R.I.M.T.	O.M.T.	MISCELL.
MIXED DENTITION	62	3	4	5	6	1	1
PERMANENT DENTITION	4	1			8	1	1

Miscell. = Combination of various methods. For key to other abbreviations *see text*.

Findings.—The angles examined were those showing changes which were considered to be related to the appliance treatment. The angles have already been enumerated, but they are repeated here for convenience. Upper and lower incisal inclinations: the angles SNA and SNB expressed in terms of the A/B difference. The angle of convexity, the Y axis, the angles of the occlusal and mandibular planes to the cranial base, and the mandibular angle.

The effect upon these angles of appliance treatment is best illustrated by a simple case (M.M.17) in which the immediate 'after treatment' changes were as follows:—

	Before Treatment	*After Treatment*	*Change in Angular Measurement*
Age (yr./mth.)	10/3	11/1	—
U.I.	88·5°	97·0°	+8·5°
L.I.	88°	82°	−6°
A/B	−0·5°	0·0°	+0·5°
∠Con.	−3·5°	−3·0°	+0·5°
Y.Ax.	64°	66°	+2°
O.P.	21·5°	17·5°	−4·0°
Mn.P.	29·0°	30·5°	+1·5°

The active treatment consisted in the proclination of the upper incisors 8·5° and the other angular changes followed from this. Spontaneous retroclination of the lower incisor is typical and is probably due to lip pressure following the removal of the forward force from the reverse overbite of the upper incisor. The positive gains in the A/B difference, the angle of convexity, Y axis, and mandibular plane angle result from the mandible not swinging so far forward and upward following the incisal correction. The decrease in the occlusal plane angle of 4° is due to the anterior determinant of the plane—the tip of the upper incisor—being moved forward and upward. It may also be due in some instances to vertical eruption of the upper molar, which will also decrease the angle.

Tables V–VII give the mean angular changes obtained in the principal treatment groups. It is not possible to discuss them all in detail and only a summary of the changes is given.

Summary of Changes following Appliance Treatment.—The effects of appliance treatment, when evaluated by an analysis of the angular changes following appliance treatment in 97 cases of mesioclusion, irrespective of the method of treatment, differed only in degree and showed the same general picture, which was as follows:—

An increased proclination of the upper incisors and an increased retroclination of the lower incisors. There were positive increases in the A/B difference and angle of convexity usually shown as a reduction in the original negative values for these angles. The angles of the Y axis and mandibular plane were increased and the angle of the occlusal plane was decreased. Follow-up studies in 57 of the cases treated showed, on an average, a high degree of stability as regards the alterations in the upper and lower incisal inclinations, but

there was a trend to a return to the 'before treatment' values in the other angles. The angle of convexity showed more relapse on average than the A/B difference, reflecting a relatively greater increase in basal than in direction. These individual variations result from variations in the amount and direction of growth and show that the basic pattern of growth has not been altered by appliance treatment, and that where this is unfavourable

Table V.—±Mean Changes in Angular Measurements in 62 Mixed Dentition Cases treated by U.R.A.

Angular Measurement	N.=62		N.=38	
	M_1	R_1	M_2	R_2
U.I.	+9·3	+ 2·0 to +19·5	+7·3	0·0 to +15·0
L.I.	−3·3	−12·0 to + 1·5	−3·6	−12·0 to + 1·5
A/B	+1·1	− 1·5 to + 3·0	+0·8	− 4·5 to + 2·0
∠Con.	+1·6	− 0·5 to + 8·0	+0·7	− 5·5 to + 8·0
Y Ax.	+0·9	− 1·5 to + 4·5	+0·7	− 1·5 to + 4·0
O.P.	−2·8	− 9·0 to + 2·0	−1·8	− 5·5 to + 2·0
Mn.P.	+0·8	− 4·5 to + 3·0	+0·3	− 4·5 to + 4·0

N.=Number of cases. M_1 and R_1=Mean and range of changes after treatment (62 cases). M_2 and R_2=Mean and range of later 'after-treatment' changes in 38 of the 62 cases. Average time between M_1 and M_2=2·3 yr. Range=7 mth. to 5 yr. 9 mth.

Table VI.—±Mean Changes in Angular Measurements in 6 Mixed Dentition Cases treated by T.W.A.+R.I.M.T.

Angular Measurement	T.W.A.+R.I.M.T.			
	N.=6		N.=5	
	M_1	R_1	M_2	R_2
U.I.	+8·3	+2·0 to +15·5	+8·3	+1·0 to +12·5
L.I.	−6·3	−3·0 to − 9·0	−8·0	−3·5 to −11·5
A/B	+1·6	0·0 to + 3·5	+0·9	−0·5 to + 2·0
∠Con.	+1·7	−1·5 to + 5·0	+1·3	−2·5 to + 5·0
Y Ax.	+1·3	−0·5 to + 4·0	+0·5	−2·0 to + 3·0
O.P.	−3·0	−6·5 to − 1·0	−3·9	−6·0 to − 3·0
Mn.P.	+1·7	−1·0 to + 4·0	−0·6	−3·5 to + 4·0

N.=Number of cases. M_1 and R_1=Mean and range of changes after treatment. M_2 and R_2=Mean and range of later after-treatment changes. Average time between M_1 and M_2=2·4 yr., range 1–4 yr.

alveolar mandibular prognathism with growth which agrees with the findings of a comparison of Class III samples of different developmental ages (Hopkin, 1961). The mandibular angle increased in some cases and decreased in others, in contrast to the consistent tendency to decrease in the deciduous dentition.

Individual cases varied in the direction of change after treatment. Some cases showed continuing increases in the angular changes resulting from treatment, whilst others showed little change or a return to the 'before treatment' values, or even a change in the opposite

Table VII.—+Mean Changes in Angular Measurements in 8 Permanent Dentition Cases treated by T.W.A.+R.I.M.T

Angular Measurement	T.W.A.+R.I.M.T.	
	M.	R. (N.=8)
U.I.	+5·3	+0·5 to +9·5
L.I.	− 6·4	−1·0 to −2·5
A/B	+0·8	0·0 to +2·0
∠Con.	+0·9	−1·0 to +3·5
Y Ax.	+0·7	−1·0 to +2·0
O.P.	−3·3	0·0 to −6·0
Mn.P.	+0·3	−1·0 to +1·5

M.=Mean. R.=Range. N.=Number of cases.

it will nullify any improvement in mandibular position effected as a result of the occlusal readjustment. This is not to deny the helpful influence of treatment where the growth pattern is basically favourable. The influence of growth upon the stability of the changes effected by appliance treatment is considered more fully in the following section, where a comparison is made between stable cases and cases that have relapsed. The occlusal changes were, of course, the correction of the reverse overjet and overbite, and approximately 1 case in 5 showed an improved molar occlusion, which implies that in the majority of cases there was no functional protrusion of the mandible before treatment.

Summary of General Changes due to Growth.—The overall picture of growth in the serial studies showed downward and forward movement of the maxilla and mandible in relation to the cranial base, and agrees with the current conception of normal facial growth. The growth of the maxilla and of the mandible varied markedly in amount and direction in different individuals. The amount and direction of facial growth did not appear to be influenced by appliance treatment. Further findings and conclusions on growth changes are given in the following section.

3. Comparison of the Treatment and the Growth Changes in a Series of Relapsed Cases with those in a Series of Successfully Treated Cases.—The 19 cases which relapsed or were unsuccessfully treated have been analysed and compared with 10 successfully treated cases, of which half have been stable for over five years, 4 for over four years, and 1 for nearly four years, the purpose of the comparison being to try to determine the treatment and growth factors that make for stability or relapse or failure in treatment. In this latter respect it has already been noted there were 9 cases in the clinical material which were judged untreatable by orthodontic means at the initial examination. These cases have not been discussed as it was thought more profitable to examine the cases which were judged clinically to be treatable, but which turned out to be untreatable or in which partial success only was achieved.

The cases under the heading 'relapsed' consisted of:—

a. Complete Relapse (C.R.).—Cases which had been successfully treated and were stable for a period before relapsing completely.

b. Partial Relapse (P.R.).—Successfully completed cases which were stable for a time and then partially relapsed to a stable position.

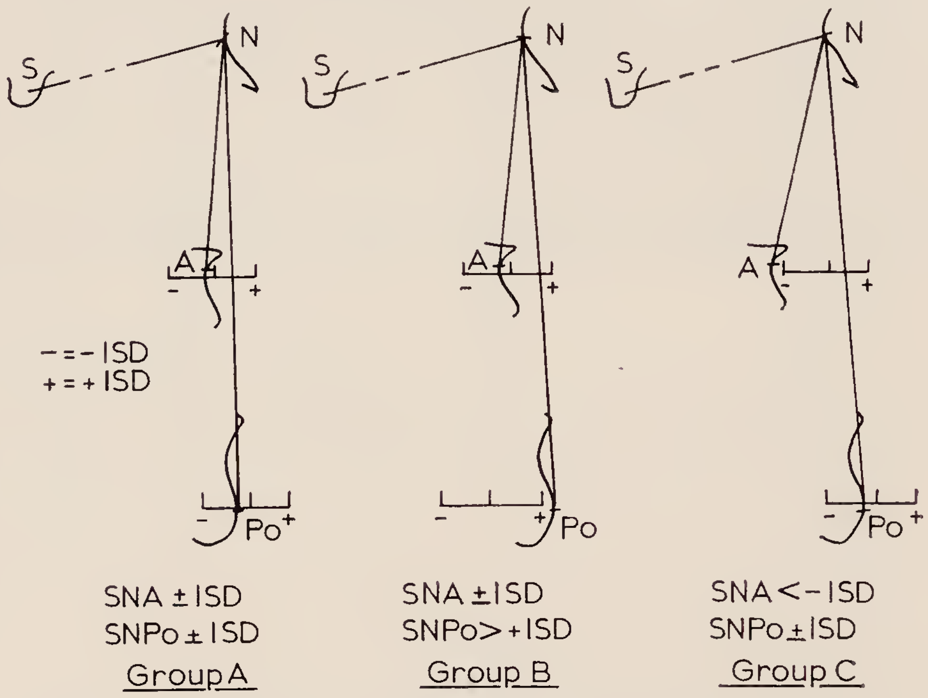

Fig. 2.—Differential analysis; for explanation *see text.*

c. Unsuccessful (U.S.).—Cases in which treatment was unsuccessful despite the patient's co-operation.

d. Observation (O.).—Cases which were under observation only and showed an increase in the degree of mesioclusion. The number of cases in each category was: C.R., 9; P.R., 5; U.S., 2; O., 3.

The cases were compared by tabulating the following data:—

i. The ABC grouping (differential analysis) (*Fig.* 2).

ii. The age at the first and final examinations and the period of observation.

iii. The method of appliance treatment.

iv. The original A/B difference, the angle of convexity, and the angle of the Y axis.

v. Angular changes during the period of observation which were recorded as the difference between the original measurement and the last recorded measurement—the net angular change.

The results are shown in *Table VIII*, stable cases, *Table IX*, female relapse cases, and *Table X*, male relapse cases. *Table XI* compares the mean net angular changes in the

Table VIII.—Data for 10 Stable Cases

Case No.	M.F.1	M.F.4	M.F.8	M.F.37	M.F.43	M.F.48	M.M.24	M.M.21	M.M.36A	M.M.56
1. I.G.	A	B	B	A	B	A	A+	A	B	A
F.G.					No change					
2. I.A.	7/–	8/9	8/2	9/2	9/11	8/11	8/–	7/10	8/8	11/1
F.A.	11/1	13/10	13/8	13/9	14/8	14/3	13/6	13/1	13/5	16/3
P.O.	4/1	5/1	5/6	4/7	4/9	5/4	5/6	5/3	4/9	3/8
3. App.	C.L.I.P.	U.R.A.	R.A.	U.R.A.	U.R.A.	U.R.A.	L.R.A.	T.W.A.	U.R.A.	T.W.A.
4. Orig. A/B	−3·5	0·0	−2·0	+0·5	−2·0	+1·0	+1·5	+1·5	−1·5	−4·5
Orig. ∠Con.	−4·0	−1·5	−8·0	−1·5	−8·0	+2·0	+3·5	+3·5	−3·5	−7·0
Y Axis	63·0	64·0	60·0	66·0	63·5	67·0	62·5	60·0	61·0	63·0
5. Net Changes in Angular Readings between I.A. and F.A.										
U.I.	+13·0	+7·5	+4·5	+5·0	+14·5	−3·3	−6·0	+12·0	+10·0	+12·5
L.I.	−2·5	−2·0	+0·5	−4·0	−9·0	−4·0	−0·5	−10·5	−7·5	+1·5
A/B	+4·5	+1·5	+1·5	−2·0	−1·0	+3·0	−1·5	−1·0	0·0	+0·5
∠Con.	+5·0	−2·5	+0·5	−5·5	−5·0	+3·0	−0·5	−3·5	+0·5	−2·0
Y Axis	0·0	−1·5	−1·0	0·0	−0·5	+3·0	+3·0	+0·5	+0·5	+3·0
O.P.	−4·0	−5·0	−2·5	−2·5	−2·5	+1·5	+0·5	−3·0	−3·0	−3·5
Mn.P.	−4·0	−3·0	−4·5	−2·0	−3·5	+1·5	+0·5	0·0	−1·5	+1·0
Mn.∠	−1·5	−4·0	−2·5	−5·0	−3·5	+3·5	0·0	−1·5	+1·0	0·0
Mx.P.	0·0	+1·0	−0·5	+1·0	−0·5	+1·5	+3·0	−1·0	+3·0	+2·0

Note: A+ = Mx. > +1 SD. Mn. > +1 SD.
I.G. and F.G. = Initial and final A,B,C grouping. I.A. and F.A. = Initial age and final age. P.O. = Period of observation. App. = Appliance employed. Orig. = Original. Key to abbreviations for angles and appliances given earlier in text.

Table IX.—Data for 9 Relapsed Cases (Female)

Case No.	M.F.10	M.F.13	M.F.18	M.F.22	M.F.39	M.F.55	M.F.66	P.F.7	P.F.31
Relapse	C.R.	C.R.	O.	P.R.	C.R.	U.S.	P.R.	C.R.	C.R.
1. I.G.	B	B	B	B	B	B	B	A	B
F.G.	B	B	B	B	B	B	B	A	B
2. I.A.	7/3	9/11	13/–	10/10	8/2	8/10	8/3	9/11	8/9
F.A.	13/2	13/1	16/–	16/2	13/7	12/8	13/7	15/3	14/7
P.O.	4/11	3/2	3/–	5/4	5/5	3/10	5/4	5/4	5/10
3. App.	U.R.A.	R.A.	O.	U.R.A.	U.R.A.	O.M.T.	U.R.A.	U.R.A.	L.R.A.
4. Orig. A/B	+1·5	−4·0	−0·5	−5·5	−1·0	−4·0	0·0	+0·5	−3·5
Orig. ∠Con.	+7·0	−9·5	−4·0	−14·0	−5·5	−9·0	−2·0	0·0	−9·0
Orig. Y Axis	63	63	65	66	63·5	60	63	68	59
5. Net Changes in Angular Readings between I.A. and F.A.									
U.I.	−3·0	+9·0	+5·0	+1·5	−2·0	+3·5	+10·0	+3·5	+3·0
L.I.	+3·5	−2·0	−1·0	−5·0	−6·5	−6·0	−2·0	−11·5	−6·5
A/B	−0·5	−1·5	−2·5	−1·0	−3·0	−2·0	−4·0	−3·5	−2·0
∠Con.	−3·5	−5·5	−5·0	−3·0	−5·5	−5·0	−9·0	−9·5	−5·0
Y Axis	0·0	+1·5	−1·5	−0·5	−1·0	−0·5	−1·0	−1·5	−3·0
O.P.	−1·0	−1·0	−2·0	−3·5	−6·0	−2·0	−1·5	−0·5	−8·5
Mn.P.	−3·0	+1·5	0·0	−3·5	+2·0	+3·0	−2·0	−1·5	−3·5
Mn.∠	−3·0	0·0	−1·5	−2·0	+2·5	−0·5	−4·0	0·0	−4·0
Mx.P.	−0·5	−1·0	+1·0	+0·5	+0·5	−1·0	+2·0	+2·5	+1·5

I.G. and F.G. = Initial and final A,B,C grouping. I.A. and F.A. = Initial age and final age. P.O. = Period of observation. App. = Appliance employed. Orig. = Original. Key to abbreviations for angles and appliances and degree of relapse given earlier in text.

‘stable’ and ‘relapse’ groups. Illustrations of stable cases are given in *Figs.* 3–8; relapsed cases are illustrated in *Figs.* 9–12. Except where otherwise indicated A shows the skulls superimposed on SN with S coincident, B shows the maxilla superimposed on ANS–PNS with PNS coincident, and C the mandible superimposed on MP with Gn coincident.

Before discussing the findings it is necessary to explain the ABC differential analysis group. In another part of the study of which this paper forms a part, the linear and angular measurements of the craniofacial pattern in Class III patients were compared with those of patients with neutroclusion. The cases were grouped according to the degree of maxillary and mandibular prognathism as measured by the angles SNA and SNPO respectively. The standard of normal was plus or minus one standard deviation of the mean value of these angles for the neutroclusion samples. Three principal groups emerged: They were Group A, in which both maxillary and the mandibular prognathism were within plus or minus one standard deviation of the mean value of neutroclusion; Group B, in which maxillary prognathism was within plus or minus one standard deviation and that of the mandible

Table X.—Data for 10 Relapse Cases (Male)

Case No.	M.M.11	M.M.18	M.M.22	M.M.29	M.M.33	M.M.43	M.M.62	P.M.5A	P.M.S.	P.M.11
Relapse	C.R.	O.	U.S.	O.	P.R.	C.R.	P.R.	C.R.	C.R.	P.R.
1. I.G.	A	A	A	B	B	A	A	A	A+*	B
F.G.	Mx.—* Mn.+	A	B	B	B	A	A	B	B	B
2. I.A.	10/8	10/8	13/7	11/5	9/1	7/10	10/4	14/4	14/4	13/7
F.A.	15/3	13/4	17/8	14/6	13/8	13/1	15/4	17/9	17/2	17/9
P.O.	4/7	2/8	4/1	3/1	4/7	5/3	5/–	3/5	2/10	4/2
3. App.	U.R.A.	O.	R.I.M.T.	O.	U.R.A.	U.R.A.	R.I.M.T.	R.I.M.T.	R.I.M.T.	R.I.M.T.
4. Orig. A/B	−0·5	+1·5	−1·5	−2·5	−2·0	−1·0	−1·5	−3·0	−4·0	−2·5
∠Con.	−4·0	+2·5	−4·0	−11·5	−5·0	−1·0	−4·0	−8·0	−12·0	−7·0
Y Axis	69·0	75·0	68·0	67·0	61·0	64·0	70·5	65·5	64·0	68·5
5. Net Changes between I.A. and F.A. in Angular Readings										
U.I.	−7·5	+5·5	+6·0	−4·0	0·0	−1·0	+10·0	−2·0	+3·5	+6·5
L.I.	−1·5	+6·5	−4·0	0·0	−1·5	−9·5	−5·0	0·0	−8·0	0·0
A/B	−4·0	−0·5	−3·0	−0·5	−1·5	0·0	−0·5	−2·0	−3·5	−0·5
∠Con.	−10·0	−2·5	−8·0	−2·5	−2·5	−1·0	−2·5	−7·0	−7·0	−1·5
Y Axis	−2·0	+0·5	−2·0	−0·5	−2·0	+3·5	−1·0	−0·5	0·0	−1·0
O.P.	+6·5	−2·0	−6·0	+8·5	+1·5	−2·5	−6·0	−2·0	−1·0	−10·5
Mn.P.	−2·0	+1·0	−13·5	−0·5	+0·5	−5·0	−2·5	−3·0	0·0	−2·0
Mn.∠	+1·5	+0·5	−0·5	−2·0	−2·5	+3·0	−1·0	+1·0	+1·0	+0·5
Mx.P.	+2·0	0·0	−1·5	+1·5	0·0	−2·5	−0·5	+1·5	−1·0	−1·0

I.G. and F.G. = Initial and final A,B,C groups. I.A. and F.A. = Initial age and final age. P.O. = Period of observation. App. = Appliance employed. Orig. = Original. Key to abbreviations for angles, appliances, and degree of relapse given earlier in text.

* *Note*: Mx.—Mn.+ = Mx. <—1 SD. Mn. > +1SD.
A+ = Mx. > +1 SD. Mn. > +1 SD.

Table XI.—Mean Net Angular Changes in 10 Stable and 19 Relapse Cases over the Period of Observation

	U.I.	L.I.	A/B	∠Con.	Y Axis	O.P.	Mn.P.	Mn.∠	Mx.P.
Stable (10)	+6·9	−5·0	+0·5	+0·7	+0·7	−2·1	−1·2	−1·3	+0·9
Relapse (19)	+2·4	−3·0	−1·2	−4·8	−0·6	−2·0	−1·7	−0·5	+0·2

was greater than +1 SD of the corresponding neutroclusion mean—this group was labelled 'mandibular protrusion'; and Group C, which consisted of those cases in whom the maxillary prognathism was more 'minus' than −1 SD of the neutroclusion mean, while that of the mandible was within + or −1 SD. These cases were called 'maxillary retrusion', and the three groups are referred to for convenience as Groups A, B, and C respectively (*Fig.* 2).

FINDINGS.—

Prognosis.—An examination of the 'before treatment' measurements for A/B difference, angle of convexity, angle of the Y axis, and degree of reverse overjet and overbite failed to show any consistent differences of prognostic value between the stable and relapsed group or between the different categories of relapse within the relapsed group.

Comparison of Mean Angular Changes.—The incisal changes are smaller in the relapsed group. The A/B difference shows a mean negative increase of 1·2° compared with a mean positive increase of 0·5° in the stable cases. The most marked difference is in the mean angle of convexity which has increased −4·8° in the relapsed compared with −1·0° in the stable group. The Y axis shows a slight positive change in the stable group and a slight negative change in the relapsed group. The occlusal plane angle, mandibular plane angle, and the mandibular angle all show a decrease of varying degree in both groups. The maxillary plane angle shows a positive change in both groups, greater in the stable group, but both under one degree. As in all the other comparisons made of the material in this study the picture given by the mean values of a measurement for any group is contradicted in one respect or another by the individuals making up the group. The mean value of any character measured is a useful fiction not to be confused with reality. It is true that individuals will be found displaying mean values for one or two measurements, but to find any number of mean values appearing in one individual is highly improbable. It is the combination of the variations in the parts and relationships observed that produces the infinite variety of individual patterns.

A study of the individual cases brings this out; the one consistent feature in all the relapsed cases is a negative increase in the angle of convexity. For any other value examined there is always at least one individual who does not conform to the general pattern. This also applies to the stable cases; for instance, *Cases* M.F.43 and M.F.48 have both been stable for 4–5 years and show no signs of relapse, having come safely through the pubertal growth spurt. The net angular changes in these cases are in marked contrast. Except for an increased retroclination of the lower incisors in both cases every other angle shows an opposing value.

The consistent negative increase in the angle of convexity in all the cases in the relapsed group was regarded as the most significant finding pointing to an increase in mandibular basal prognathism relative to maxillary prognathism as the primary factor in relapse. An increase in mandibular prognathism relative to maxillary prognathism with age is a feature of normal facial growth. It prompts the suggestion that the cause of the Class III relapses is an exaggeration of a normal growth trend, either by excessive mandibular growth or by normal mandibular growth and deficient maxillary growth.

These possibilities were investigated by comparing the A, B, C grouping of the relapsed and stable cases at the beginning and end of treatment, and by the study of growth in individual stable and relapsed cases by means of the superimposition of the serial tracings.

An examination of *Tables VIII–X* shows that in the stable group there was no change in the individual A, B, C grouping over the observation period. In the relapsed cases there was no change of group among the females, but of the males 3 Group A cases had become Group B cases at the end of the observation period and 1 case fell into the extreme group of maxillary mandibular mal-relationship—maxillary prognathism more 'minus' than −1 SD and mandibular greater than +1 SD. It will be noted that of the female relapse cases 8 of the 9 cases were Group B initially (that is, mandibular protrusion) and these could not necessarily be

expected to show any further change in group, if maxillary growth was still sufficient to keep the degree of maxillary prognathism within -1 SD of normal. On the other hand, 4 of the 7 male Group A cases showed a worsening in maxillary—mandibular relationships severe enough to be detected by the relatively coarse standard of $+$ or -1 SD. These results confirm the pointer, given by the comparison of means in the relapsed and stable groups, of a relative increase in mandibular protrusion being the cause of relapse. This relative increase in mandibular protrusion could be due to an excess of mandibular or a deficiency of maxillary growth.

Consideration is therefore now given to the amount and direction of growth in individual cases in the stable and relapsed groups to see if this factor, the ratio of maxillary to mandibular growth, is the cause of success or failure.

This comparison of growth in the stable and relapsed cases will show that the main difference between the two groups lay in the patterns of maxillary and mandibular growth.

Both maxilla and mandible showed variations in the amounts of their horizontal and vertical growth which was reflected in the amounts of their forward and downward movement and in the direction of the resultant of these components.

The amount of downward and forward translation of the chin was also affected by a third variable, the extent and direction of the change in the position of articulare. This point is taken as approximating the temporomandibular joint. In serial growth studies it behaves like the related point porion, and moves downwards and backwards relative to the plane of superimposition.

This apparent bodily backward movement of the mandible relative to the maxilla will be shown to be a crucial factor in determining stability or relapse. A greater than average backward movement will counterbalance an excess of mandibular over maxillary forward growth, whilst a less than average degree of backward displacement characterized by an almost wholly vertical descent of articulare will cause relapse where mandibular growth itself is not excessive relative to that of the maxilla.

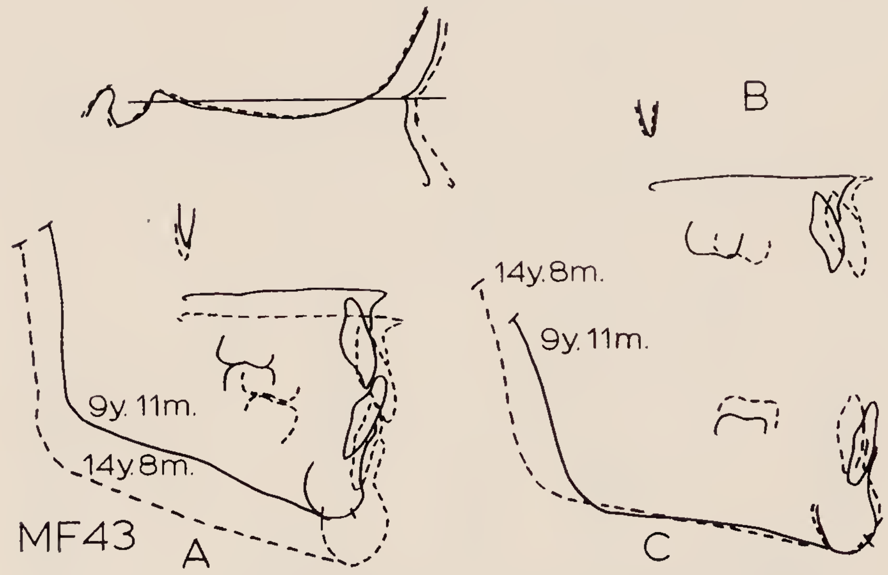

Fig. 3.—*Case* M.F.43. Stable case, greater mandibular than maxillary growth offset by greater backward translation of articulare (cf. *Fig.* 12).

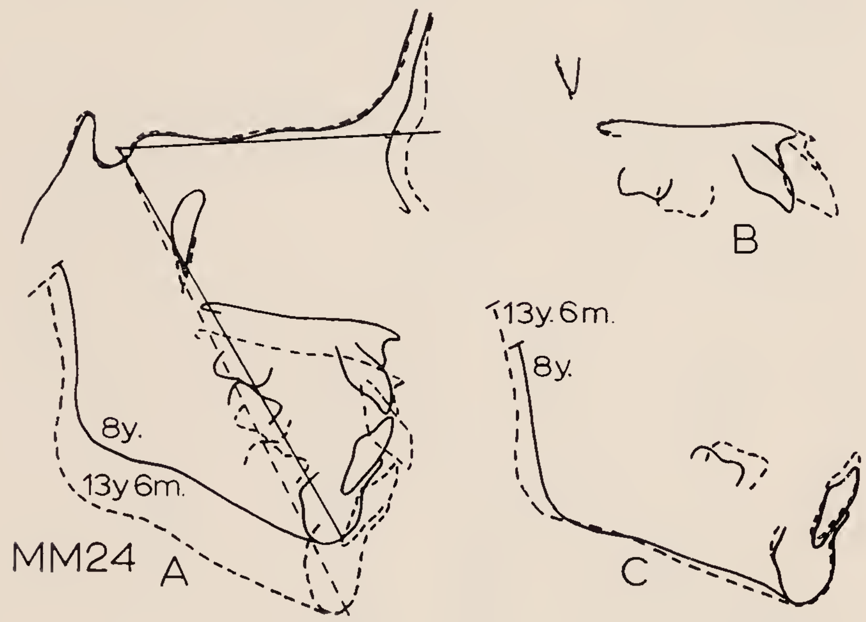

Fig. 4.—*Case* M.M.24. Stable case, proportionate maxillary mandibular forward growth, average backward translation of articulare.

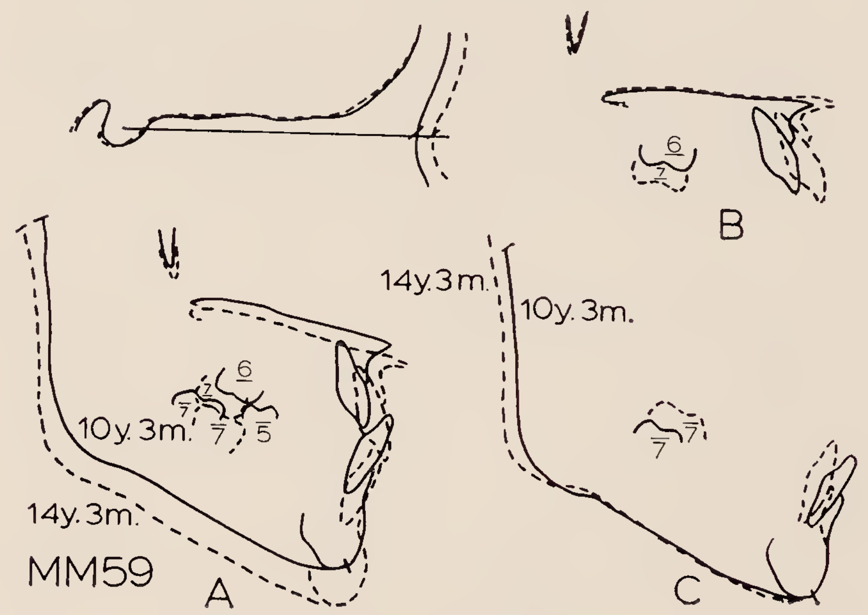

Fig. 5.—*Case* M.M.59. Stable case, proportionate maxillary mandibular forward growth, average backward translation of articulare.

It is not possible to give the growth histories of all the 29 patients, and typical cases from each group only are shown. For convenience ages are indicated as follows: 9/11 =9 years 11 months.

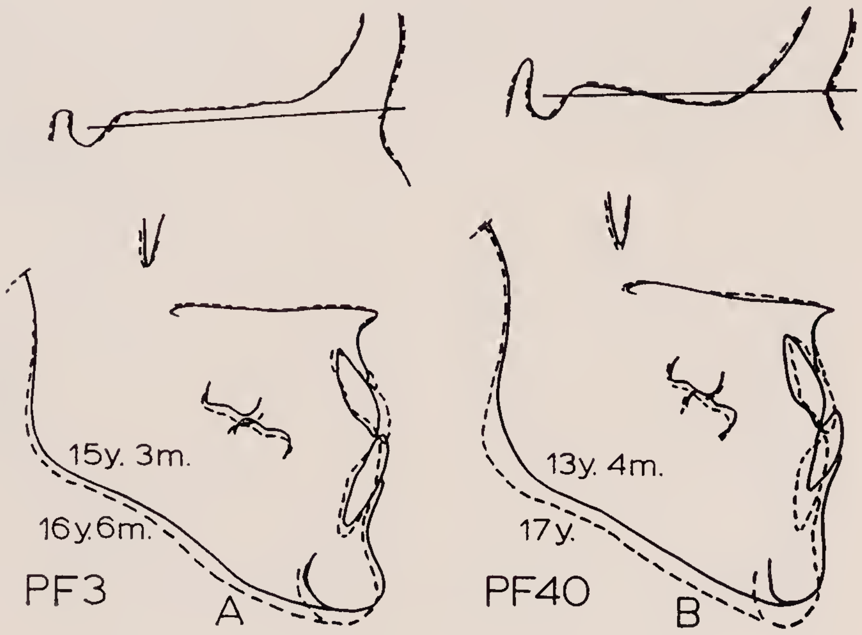

Fig. 6.—*Cases* P.F.3 and P.F.40. Stable cases before and after correction, negligible maxillary growth in either case. No forward mandibular growth (cf. *Figs.* 7, 8).

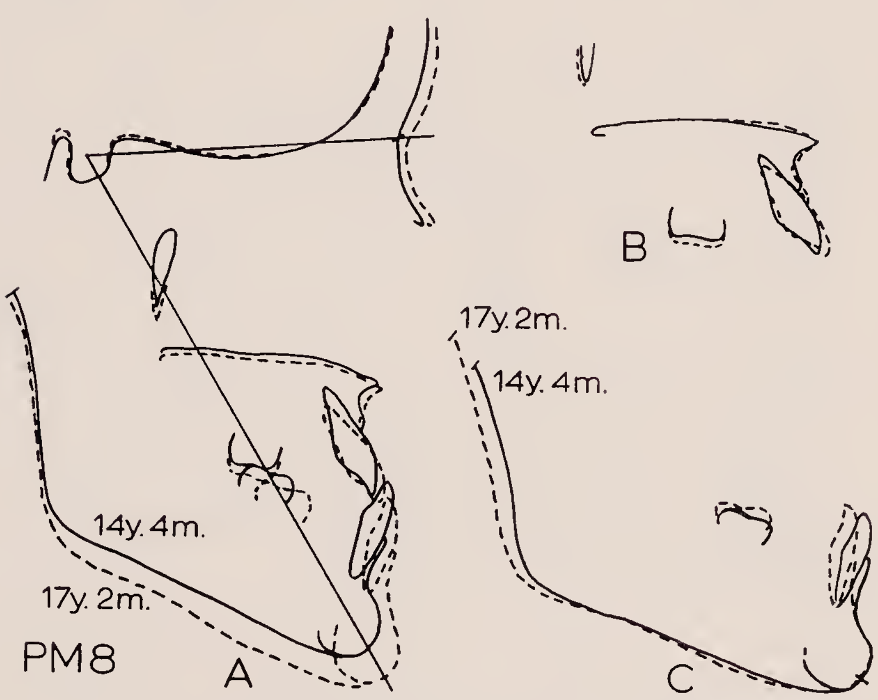

Fig. 7.—*Case* P.M.8. Stable case, maxillary and mandibular growth, little backward translation of articulare.

Stable Cases.—*Case* M.F.43: 9/11–12/8, proportionate maxillary and mandibular growth; 12/8–14/8, slight maxillary growth with fairly marked mandibular growth forwards and vertically. Despite this unfavourable trend shown by the marked negative increase in the angle of convexity the occlusion remained stable; a factor in the stability of the occlusion may be the amount of backward displacement of articulare (*Fig.* 3).

Case M.M.24: 8/0–11/10, proportionate growth in both jaws more vertical than horizontal in the mandible and less vertical than horizontal in the maxilla (*Fig.* 4).

The following cases are not included in the series of 10 stable cases, but are included to show the varying growth patterns of maxillary and mandibular growth in treated cases:—

Case M.M.17: 10/3–14/2, proportionate growth of jaws with some backward placement of articulare, symphysial remodelling.

Case M.M.59: 10/3–14/3, proportionate growth of maxilla and mandible with mandible showing more backward than forward placement (*Fig.* 5).

Case M.M.61: 10/5–13/11, slight growth in either jaw and little backward displacement of articulare compared with *Case* M.M.17 *above.*

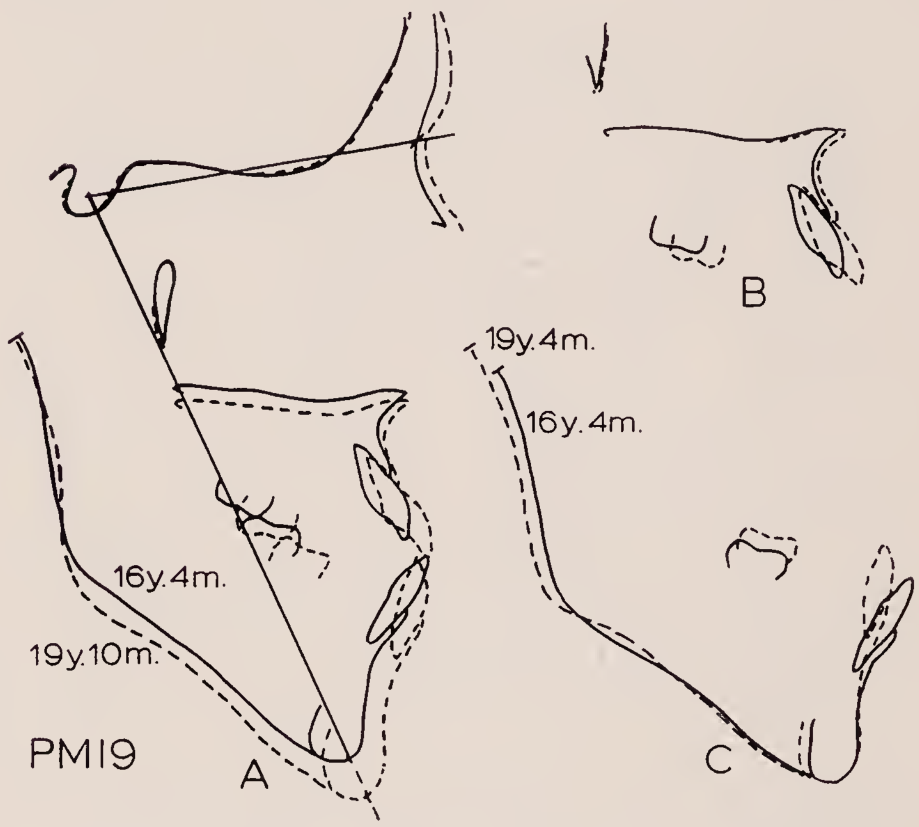

Fig. 8.—*Case* P.M.19. Stable case, showing maxillary and mandibular growth 16 yr. 4 mth.–19 yr. 10 mth., contrasting with lack of growth in female cases in mid teens (*Fig.* 6).

Case P.F.3: No obvious growth between 15/3 and 16/6 (*Fig.* 6 A).

Case P.F.40: Slight growth 14/4 and 17/0 (*Fig.* 6 B).

Case P.M.19: Growth increments 16/4–19/10 (*Fig.* 8).

Growth Changes in Relapse Series (C.R.).—Cases showing complete relapse—*Case* M.F.39, 8/2–11/6, general maxillary and mandibular

growth, correction stable 9/1–11/6; 11/6–13/7, very slight maxillary growth, the mandible shows continued downward and forward growth with marked accretion at the symphysis. Incisor occlusion relapsed (*Fig.* 9).

Case M.M.11: Treatment started 8/6, continued until 10/8, correction being obtained with difficulty and relapsing almost immediately. Cephalometric records of relapse

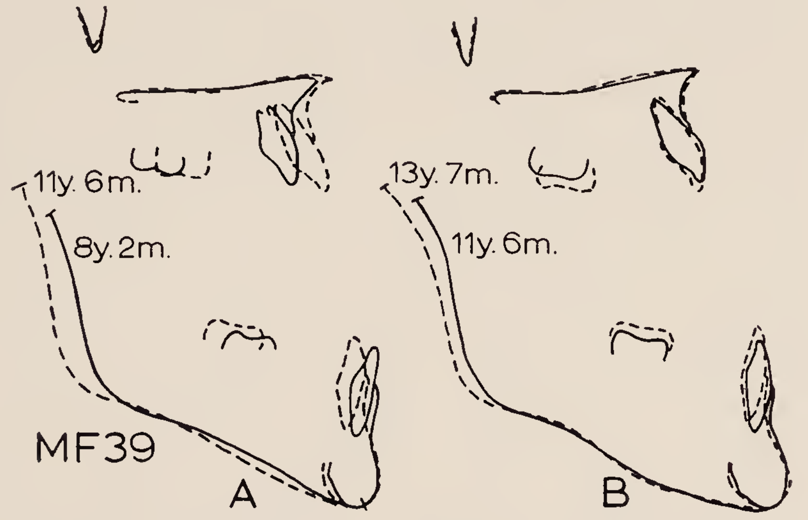

Fig. 9.—*Case* M.F.39. Relapse. A, Stable 8–11 yr. B, Relapse 11–13 yr. Note proportionate growth of both jaws 8–11 yr. and lack of maxillary growth 11–13 yr.

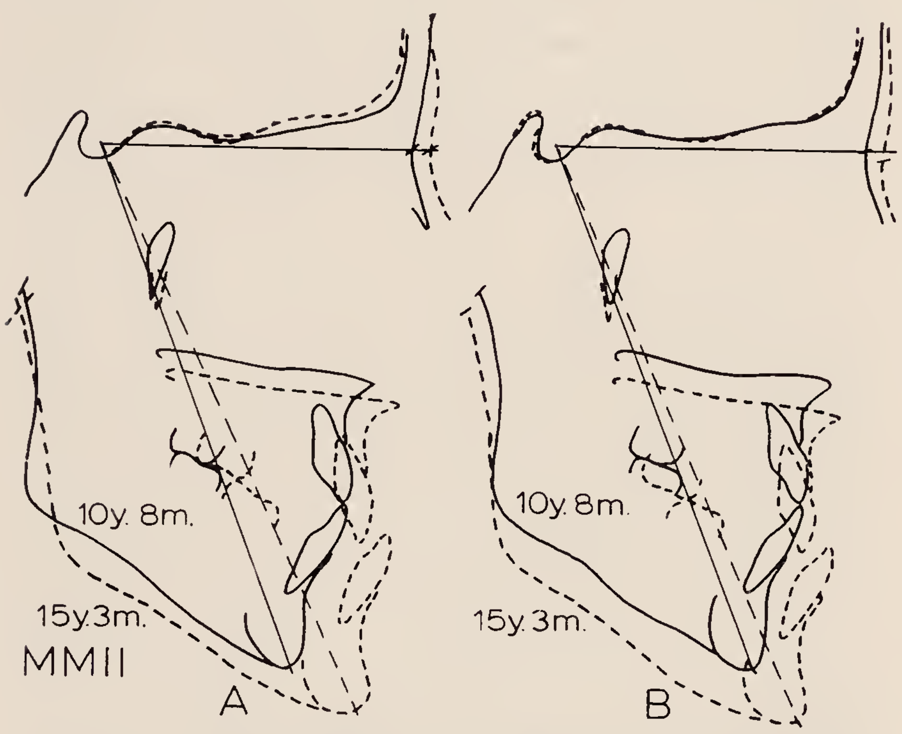

Fig. 11.—*Case* M.M.11. Relapse case. The relapse followed repeated corrections and the case became untreatable orthodontically at adolescence. Superimposition on SN in (A) and on De Coster's line in (B). The latter shows descent of nasion.

only, 10/8–13/4, slight maxillary growth with moderate mandibular growth more forward than downward. 13/4–15/3, maxillary growth slight, marked vertical mandibular growth with opening of the mandibular angle, the forward component of vertical growth resulting in an increase in the reverse overjet (*Fig.* 11).

Case P.F.7: 9/11–11/11, moderate growth in both jaws; 11/11–14/2, moderate maxillary with marked mandibular growth associated with relapse; 14/2–15/3, no maxillary

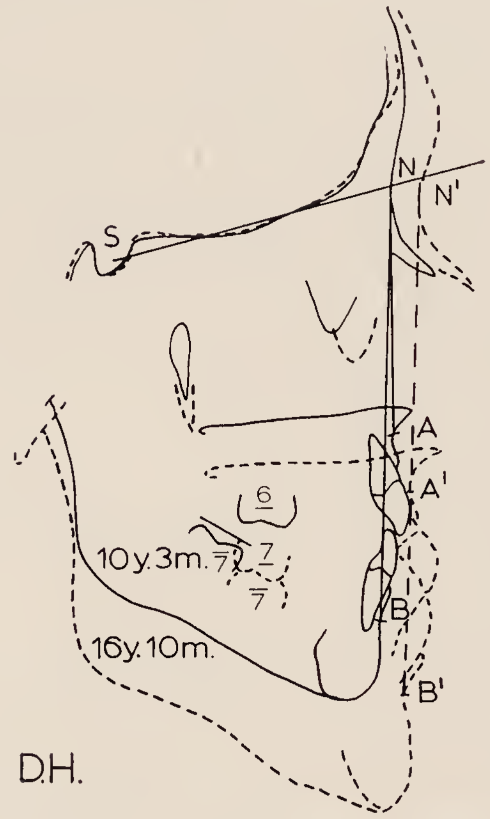

Fig. 10.—*Case* D.H. Relapse case. Stable 10–14 yr., relapse 14 yr. onwards, with continuous loss of overbite. Note vertical growth dominant.

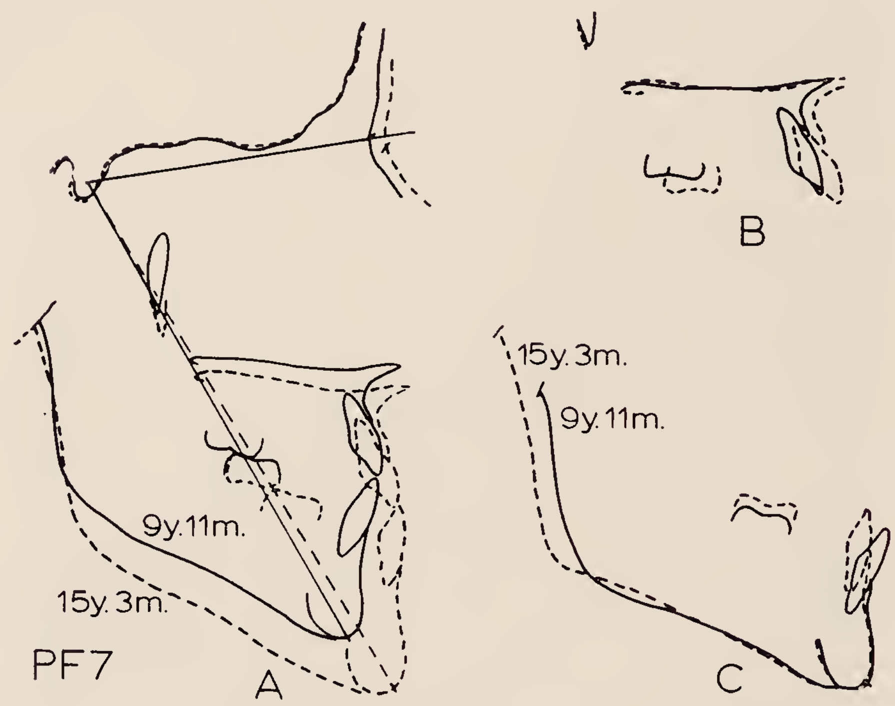

Fig. 12.—*Case* P.F.7. Relapse case, horizontal mandibular growth not disproportionate to maxillary but only slight backward translation of articulare (cf. *Fig.* 3).

growth, slight vertical mandibular growth (*Fig.* 12).

Case P.F.31: Stable after correction from 9/6–11 plus, having relapsed by 12/6. (The radiograph taken at 8/9 was not taken in the cephalometer and cannot be used for linear comparisons.) 12/6–14/7, slight maxillary

forward growth compared with mandibular growth, which itself is not marked, suggesting that the main spurt in mandibular growth occurred before 12/6.

Growth Picture in Cases showing Partial Relapse (P.R.).—

Case M.F.66: 8/3–12/6, general maxillary and mandibular growth with that of the mandible relatively greater. Symphysial accretion increasing the negative angle of convexity, but the occlusion was stable. 12/6–13/7, negligible maxillary growth—mandibular growth marked vertically with no forward growth, accompanied by a change in the incisal relationship from an overjet to an edge-to-edge bite of the incisors with retroclination of the upper incisors.

Case P.M.11: Correction with overjet and overbite 14/5. Growth record: 13/7–15/11, general growth of both jaws with marked vertical growth of the mandible. Incisor bite remained stable. 15/7–17/9, no perceptible increase in maxillary growth forwards with marked vertical and slight forward growth in the mandible. The incisor bite relapsed to edge-to-edge.

Unsuccessful Cases (U.S.).—

Case M.F.55: Occipitomental traction applied for 18 months without success and referred for surgical correction; poor prognosis initially. Growth record: 8/10–12/8, small amount of maxillary growth, with an average amount of mandibular growth.

Case M.M.22: Considerable previous treatment to proclinate the incisors without success. Some success was achieved by fixed appliance, followed by immediate relapse. Growth record: 13/7–15/9, poor maxillary growth, good mandibular growth; 15/9–17/8, negligible maxillary growth with some mandibular growth.

Cases under Observation only (O.).—

Case M.M.29: Slight mesioclusion with normal overjet and overbite. Disappearance of overjet and decreased overbite, increased mesioclusion during observation period. Growth record: 11/4–14/6, forward maxillary growth with marked mandibular vertical growth, but little horizontal growth and symphysial accretion.

Case M.F.18: Mesioclusion with normal overbite and congenital absence of $\overline{1|1}$. Incisor occlusion changed from an overbite to an edge-to-edge occlusion over the observation period. Growth record: 13/0–16/0, slight maxillary growth with positive mandibular growth most marked vertically.

Summary and Discussion.—The comparison of growth in the two groups made on a subjective basis shows differences of sufficient degree to be detected by this method of assessment. The principal factor appears to be the relative amounts and direction of maxillary and mandibular growth taking place over any period. Examination of the stable cases shows a fairly consistent pattern of joint activity or relative quiescence of growth. There is a tendency for mandibular growth to be greater than maxillary in the later periods. The patterns of maxillary and mandibular growth in the relapsed groups show a much lesser degree of synchronization. In the earlier period both jaws were growing equally. As time passes maxillary growth slows down considerably or becomes negligible in the majority of cases, whilst mandibular growth persists. This results in a greater discrepancy in the relative amounts of growth of the jaws than occurs in the stable cases. As already mentioned, some increase in mandibular prognathism relative to that of the maxilla in the later stages of growth is part of the normal developmental pattern. The fault in the relapsed cases may be a premature slowing of maxillary, or a delayed slowing down of mandibular growth, or a combination of these factors. That a deficient growth potential in the maxilla may be a factor in some cases is suggested by *Case* M.F.55, which showed markedly below average increments of maxillary growth from the age of 8 years 10 months. The site and direction of mandibular growth play a part in determining the stability of the result. *Case* M.F.3 is a stable case, but the angular changes suggest a relapse. This case shows marked mandibular growth, but at the same time as the gnathion has moved downwards and forwards the articulare has moved downwards and backwards to a greater extent than is seen in other cases, e.g.,

Case P.F.7, which is a relapse case. The amounts of horizontal and of vertical growth of the mandible vary. In some cases they are proportionate, in others one predominates over the other. It has been shown in a previous study (Hopkin, 1961) that in both neutroclusion and Class III cases, during growth, mean mandibular height increased more than horizontal length. In *Case* P.F.31 horizontal growth appears to be the major factor in producing the marked relapse. Where vertical growth is predominant the effect is to reduce the overbite rather than increase the antero-posterior discrepancy. This is well shown, both in the stable and relapsed cases. Decreases of overbite, varying in degree, associated with marked increases in the vertical component of mandibular growth are seen in *Cases* M.F.4, M.M.29, and P.M.11. In *Case* M.F.4 there was still an overbite, but in the other cases the bite became edge-to-edge. This is clearly again a matter of degree and is an exaggeration of normal developmental processes. The remodelling of the symphysis, termed 'symphysial accretion', increases the negative value of the angle of convexity, as seen in a number of cases, both stable and relapsed, but does not appear to be a causal factor in relapse.

The time of relapse was of interest, tending to occur later in boys than in girls, and to be associated in several cases with the adolescent growth spurt. In girls relapse appears to set in around 11 years, as in *Case* M.F.39; taking this as a typical example, the incisor correction remains stable for over 3 years, relapsing coincident with the general physical pre-menarche development. A similar picture was seen in *Case* M.F.10, which again was stable for 3 years, relapse occurring between 11 and 12 years. During this period the patient's mother remarked that she had to refit her with clothes every quarter.

Where relapse occurred in boys after a period of stability the age of onset was later, around 13–14 years, as in *Cases* P.M.5 and M.M.62. Not all the relapse cases were associated with relapse at the adolescent period following a period of stability. Several cases relapsed immediately, such as *Cases* M.M.11, M.M.43, and P.M.8. In these cases there was nothing to indicate that the basal mal-relationship was too great at the start of treatment to permit of a stable result. In such cases where records covering the period were available, such as *Case* M.M.11, a marked worsening occurred during the period of adolescence. The general picture of growth in both the stable and relapsed cases suggests a relationship with adolescence. The periods of most active growth in both jaws over the period observed (approximately 8–17 years) tended to occur earlier and die out earlier in girls than in boys. Complete serial studies are not available and accurate figures cannot be given, but the few cases observed in the older age-groups suggested that by 15 years or earlier the adolescent spurt, as regards jaw growth, had finished in the girls, maxillary growth exhausting itself earlier than mandibular, whereas in the boys maxillary growth is trailing off by 15–16 years and mandibular growth is slowing by 16–17 years. It must be stressed that these are only observations on a few cases and no generalizations are being made. It is suggested that individual studies of growth over this period in normal and abnormal occlusions would be of value. Tanner (1955) comments on the relative lack of orthodontic studies covering this aspect of facial growth. A further matter for investigation in relation to facial growth is the relative influence of the gonadotrophic hormones upon cartilaginous as opposed to appositional and sutural growth of bone, the former being the principal factor in mandibular and the latter in maxillary growth. The relatively greater mandibular than maxillary growth during the pubertal spurt is presumably a matter of hormonal control, and appears to be the critical factor in determining stability or relapse. Confirmatory evidence is seen in the marked response to treatment often seen in distoclusion cases during this period. Here the relatively greater mandibular growth is a major factor in successful treatment.

SUMMARY

A roentgenographic cephalometric analysis has been made of treatment and growth changes in 130 cases of mesioclusion.

The principal treatment and growth changes observed were as follows:—

1. Deciduous Dentition Cases (14).—

a. Occipital traction continued for as long as 5 years and had no discernible effect on the amount or direction of mandibular growth.

b. The occlusion of the permanent incisors is primarily determined by the anteroposterior basal bone relationship, and is unaffected by correction of a reverse occlusion of the deciduous incisors.

2. Mixed and Permanent Dentition Cases (97).—

a. The principal angular changes effected by treatment were proclination of the upper incisors and retroclination of the lower incisors, the latter often spontaneous. Secondarily, there were positive increases in the angle of convexity, A/B difference, and Y axis consequent upon the altered occlusal position of the mandible.

b. Occlusal changes were correction of the incisor bite and a reduction in the mesioclusion of the cheek teeth, the latter occurring mainly in cases of functional protrusion.

c. Follow-up studies in 52 cases showed the basic growth pattern to be unaffected by appliance treatment.

d. There was no difference in the general effect produced by the different forms of appliance treatment, fixed, functional, or removable.

3. Comparison of Relapse Cases (19) with 10 Cases stable for 4–5 years.—

a. No diagnostic criteria could be established in terms of the cephalometric analysis to differentiate the stable from the relapse case before treatment.

b. The principal factor in the relapse or unsuccessful treatment of mesioclusion was an unfavourable ratio of maxillary to mandibular forward growth.

c. The danger period for relapse is during the adolescent growth spurt, when a marked disproportion between maxillary and mandibular forward growth may become evident.

d. The principal factor making for stability of the occlusal correction is a favourable growth pattern.

4. Growth Changes.—

a. The anterior cranial base proper is constant in outline after about 7–8 years.

b. The mandibular angle shows a marked tendency to decrease between 4–10 years; its later behaviour is variable.

c. Extensive remodelling of the alveolar profile of the mandible occurs with the change of dentition. Later changes are accretions in the mental region.

d. Growth of the maxilla and mandible showed individual variations in direction and amount.

e. The point articulare showed variation in the degree of its backward and downward translation.

GENERAL CONCLUSIONS

1. The changes found in the craniofacial pattern in mesioclusion after appliance treatment are in general the results of growth and development, and are not related to the appliance treatment, except for changes in the dento-alveolar structures, or changes related to alterations in the mandibular position in occlusion consequent upon the correction of the incisal relationships, which are especially marked in cases showing a functional protrusion before treatment.

2. A corollary of the first conclusion is that the amount and direction of jaw growth in mesioclusion is not influenced by appliance treatment.

3. The cause of the relapse occurring in corrected cases of mesioclusion is a failure of maxillary forward growth to keep pace with mandibular forward growth.

4. This relative failure of maxillary growth tends to occur during the adolescent growth spurt.

5. The uncoordinated variability of growth, both in direction and amount, of the posterior cranial base, the maxilla, and the mandible, constitutes the imponderable element in prognosis.

Acknowledgements.—I would like to thank my colleagues, past and present, in the Orthodontic Department, University of Edinburgh Dental School, for making their Class

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DISCUSSION

Dr. L. M. Clinch, opening the discussion, said that when she was confronted with an Angle Class III malocclusion her main difficulty was to give a reliable prognosis. She had hoped that the paper would give her a firmer basis to use in future, and it was almost consoling that, even with more complicated diagnostic aids than one could use as a rule, it was not possible to be more definite.

Could Dr. Hopkin tell her, if the primary effects of orthodontic treatment were limited to the teeth and alveolar bone, what were the secondary effects which occurred in the position of the mandible consequent on the correction of the incisal relationship? Were they due to a correction of the posture of the mandible? It could be expected that that would improve the molar occlusion, but she gathered that it only occurred in 1 case out of 5. And incidentally, had it been proved that all the alveolar bone was resorbed with the shedding of a deciduous tooth?

She was very interested in Dr. Hopkin's A, B, C differential analysis of the stable cases; 6 out of 10 of the analysed cases fell into group A and, in the relapsed cases analysed, only 4 out of 19 fell into the more favourable group. This would indicate that, where there was a well-formed maxilla, the prognosis was better, and clinically, she had certainly found that where there was a maxilla the size of a pea, as she once heard Dr. Northcroft describe it, the prognosis was very unfavourable. The more favourable initial grouping among the males could be due to later development.

The marked negative increase in the angle of convexity in the relapsed group could be caused by increased forward growth of the mandible or reduced growth of the maxilla, or a combination of the two, and was, therefore, to be expected. But the relative backward movement of the mandible, which appeared to be the crucial factor in determining stability, should show an increase in the Y axis; but that occurred in only 5 out of 10 of the stable analysed cases. However, it occurred in only 1 of the relapsed cases, and in the stable cases the mean of the Y axis was $+0{\cdot}7$ compared with $-0{\cdot}6$ in the relapsed cases.

She had always felt that if she obtained a good overbite of the upper permanent incisors over the lowers, a relapse would be unlikely. Was that so?

With reference to Dr. Hopkin's summary, was it not an excess of mandibular growth during the adolescent growth period which caused a relapse rather than a relative failure of maxillary growth? As patterns of growth were hereditary, it seemed that the safest criterion on which to base prognosis was the family history.

Mr. C. D. Parker said he had two observations. The first one concerned the cases which were successfully treated from the viewpoint of the backward movement of the mandible. He wondered whether these were cases with a mandibular displacement and overclosure before treatment, and in proclining the upper incisors the position of the mandible changed.

The second point concerned the lateral skull radiographs taken in occlusion. He thought that radiographs taken with the mandible at rest rather than in occlusion were probably much more accurate in indicating the patient's facial growth pattern in this type of malocclusion. In some of the cases there was a considerable degree of overclosure which had resulted from an initial contact of the incisors and a subsequent displacement of the mandible.

Mr. G. C. Dickson said that he had two questions. The first concerned a point raised by Miss Clinch; in analysing any such serial study, one could take into account quite a number of factors in classifying the cases. Dr. Hopkin took the relative forward position of the maxillary base and the mandibular base for his three classes. Had he subjected his figures of analysis into two groups, each group representative respectively of those with a high or low Frankfurt-mandibular-plane angle? If so, did that subdivision shed any light on the figures? With that subdivision, was he able to give a different prognosis?

Secondly, did Dr. Hopkin consider that, after treatment of Class III malocclusion with a fairly large skeletal element, the bite of the incisors was frequently so traumatic as to prejudice the life of the upper incisors? He frequently wondered whether he had done a patient a service or not in reversing the incisor bite.

Dr. Hopkin, in reply to Miss Clinch, said that the question of alterations consequent upon displacement of the mandible had occurred in both her remarks and those of Mr. Parker. He had been surprised how infrequently a functional protrusion before treatment occurred; in about 1 case in 5. Very often, a case which he had clinically diagnosed as having functional protrusion

turned out, both on the basis of angular changes after treatment and of occlusal relationship of the molars, not to have been so. A deceptive appearance was sometimes produced by an overclosure of the mandible, with the chin point going upwards and forwards in occlusion. Following treatment, this overclosure was apparently eliminated. He had even seen a case which showed a hinged axis of closure before treatment and a retrusive path after treatment. He illustrated various types of cases with slides.

He felt that the optimum time for treatment was in the early mixed dentition as soon as the permanent incisors had erupted. If parents were very concerned about the condition, he might commence treatment in the deciduous dentition, but felt that judicious grinding of the canines was as effective as anything.

He had some rather interesting tracings of the changes in the alveolar bone at the shedding of the deciduous teeth. On one or two it could clearly be seen that the remains of the alveolar bone supporting a deciduous tooth were quite separate and distinct from that which was developing round the permanent incisor underneath. He did not wish to generalize from one or two cases, but he had a firm conviction that this was so.

He agreed that the prognosis for Group A cases was generally better, but every individual was a law unto himself as regards growth. One case which commenced in Group A had, by the end of treatment, both maxilla and mandible outside the range of one standard deviation and, in fact, had become untreatable. Similarly, with overbite he agreed that, generally, if there was a good overbite and no great reverse overjet, the prognosis was good, but there was always someone who spoiled it.

In reply to Mr. Parker, he agreed that one should take X-rays at rest, but this could be very difficult. It was particularly difficult to take X-rays of young children and be sure that their mandible was in the true rest position. With the occlusal position, there was little doubt.

He agreed that some backward positioning of articulare might be due to an elimination of mandibular displacement, but this effect was very slight compared with that which he had found. There seemed little doubt that growth was the main factor.

Replying to Mr. Dickson, he said that Group C on the whole had a large gonial angle whereas in Group B there was a small gonial angle. Clinically, what he had called maxillary retrusion appeared to be a mandibular protrusion, and vice versa.

He agreed that he was worried about the incisor bite becoming traumatic following treatment. The thrust was not on the functional line, but so long as the gingival fibres were there to bind and support it was all right. Once the gingival fibres went, perhaps ten or fifteen years after treatment, breakdown occurred.

Generally, he found both in prognosis and treatment clinical judgement was the final arbiter in Class III cases despite all the cephalometric analyses.

REPORTS OF MEETINGS

ORDINARY MEETING, 8 January

An Ordinary Meeting of the Society was held at Manson House, 26, Portland Place, London, W.1, on Monday, 8 January, 1962. The President, Dr. W. Russell Logan, was in the Chair.

The Minutes of the Ordinary Meeting held on Monday, 11 December, 1961, were read by the Secretary, confirmed, and signed as a correct record.

The following candidates for membership were elected:—

Mr. A. G. Beaton, B.D.S. (Lond.), M.R.C.S., L.R.C.P., 67, High Street, Aylesbury, Bucks.

Mr. D. T. Bennett, L.D.S. R.C.S., F.D.S. R.C.S., D.Orth. R.C.S. (Eng.), 43, Garth Road, Sevenoaks, Kent.

Mr. Alexander Fraser, L.D.S. (L'pool), 9, High Street, Banbury, Oxon.

Miss Margaret Claire McCall, B.D.S. (Dubl.), F.D.S. R.C.S. (Eng.), D.Orth. R.C.S. (Eng.), 8, Haresfield Gardens, Hampstead, London, N.W.3.

Mr. P. H. Morse, L.D.S. R.C.S., 1, Westwood Road, Barby Lane, Rugby, Warwickshire.

Mr. M. Savage, L.D.S. (Durham), 31, Beaumont Street, Oxford.

The President welcomed any visitors who were present. He then delivered his Presidential Address:—

'*The Effect of the Milwaukee Brace on the Developing Dentition*'

ORDINARY MEETING, 12 February

An Ordinary Meeting of the Society was held at Manson House, 26, Portland Place, London, W.1, on Monday, 12 February, 1962, at 7.30 p.m. The President, Dr. W. Russell Logan, occupied the Chair.

The Minutes of the Ordinary Meeting held on 8 January, 1962, were read by the Secretary, confirmed, and signed by the President as a correct record.

The following candidates for election were admitted *en bloc* by show of hands:—

Mr. Donald N. McLeod, B.D.S. (Edin.), D.P.D. (St. Andrews), 5, Bosville Terrace, Portree, Isle of Skye.

Mr. John Rayne, F.D.S., L.D.S. R.C.S., Dental Department, Stoke Mandeville Hospital, Aylesbury, Bucks.

The President welcomed any visitors who were present and said that he hoped they would consider themselves members of the Society for the evening, and feel themselves free to take part in any discussion.

He then introduced Mr. A. J. P. Cousins, who read a short communication entitled:—

'*Removable Appliance Technique—the Application of Rapid Cold-cure Acrylic Resin*'

Following the discussion on the short communication, the President introduced Mr. E. S. Broadway, who read his paper on:—

'*The Accuracy of Tracings from Cephalometric Lateral Skull Radiographs*'

ORDINARY MEETING, 12 March

An Ordinary Meeting of the Society was held at 26, Portland Place, London, W.1, on Monday, 12 March, 1962, at 7.30 p.m., with the President, Dr. W. Russell Logan, in the Chair.

The Minutes of the meeting held on 12 February, 1962, were read by the Secretary and signed as a correct record.

The Secretary reported that an apology had been received from Mr. and Mrs. D. Robertson-Ritchie.

Mr. A. G. Beaton was introduced to the President and formally admitted as a member.

The following candidates were elected to membership:—

Mr. H. B. Brien, B.D.S. (Sydney), D.Orth. R.C.S., 131a, Balham High Road, London, S.W.12.

Mr. V. C. West, B.D.Sc. (Melb.), L.D.S. (Victoria), 49, Westmoreland Road, Bromley, Kent.

Mr. J. P. Hughes, L.D.S. (V.U. Manc.), 135, Dowson Road, Hyde, Cheshire.

Miss E. S. Davidson, B.D.S., Little Melands, Oakway, Chesham Bois, Bucks.

The President welcomed any visitors present and said that he hoped they would feel

themselves free to take part in any discussion following the papers. He then introduced Mr. C. D. Parker and asked him to present a short communication on:—

'*A Case of Marked Asymmetry of the Face due to a Unilateral Condylar Hypoplasia*'

Mr. P. J. Blyth then presented his paper on:—

'*Mandibular Posture and Displacement*'

COUNTRY MEETING, 11–12 May

The Country Meeting of the Society was held in Adam House, the University of Edinburgh, on Friday and Saturday, 11 and 12 May, 1962.

The President (Dr. W. Russell Logan) welcomed members to the Country Meeting.

The Secretary (Mr. B. C. Leighton) read the Minutes of the previous meeting which were confirmed and signed as a correct record.

The President said that apologies had been received from Mr. W. J. Tulley and Miss L. M. Clinch.

The following candidates for membership were elected:—

Mr. A. J. Hardingham, L.D.S. R.C.S., Charlton House, Cirencester, Glos.

Miss S. V. Patwardhan, L.D.Sc. (Bombay), L.D.S. R.C.S. (Eng.), 46, Gloucester Place, London, W.1.

Mr. G. B. Winter, M.B., B.S., B.D.S., F.D.S., D.C.H., 2, Sunny Hill Court, Sunningfields Road, Hendon, London, N.W.4.

Mr. J. W. Ashby, B.D.S. (N.Z.), F.D.S., D.Orth. R.C.S., c/o Dental Department, Public Hospital, Christchurch, New Zealand. (Corresponding Membership.)

The President said that if any visitors were present, he would like to welcome them and invite them to take part in the discussions.

Papers and Demonstrations were then delivered according to the following programme:—

Programme

Friday, 11 *May*

9.30 a.m. Short Communication: Miss M. N. Miller: '*Cases treated by Expansion Appliance*'.

10.15 a.m. Short Communication: Mr. P. T. Heffer: '*Treatment of an Unerupted First Permanent Molar*'.

10.45 a.m. Coffee.

11.15 a.m. Chairman: Professor G. E. M. Hallett.

Paper: Mr. S. Haynes and Dr. D. Jackson: '*A Comparison of the Mechanics and Efficiency of* 21 *Orthodontic Expansion Screws*'.

12.45 p.m. Luncheon.

2.15 p.m. Short Communication: Mr. D. G. Huggins: '*Eruption of Lower Third Molars following Orthodontic Treatment*'.

2.45 p.m. Short Communication: Dr. J. Campbell: '*Determining Condyle Displacement in Cross-bite Cases*'.

3.30 p.m. Tea.

4.00 p.m. Short Communication: Mr. T. Cradock Henry: '*The Surgical Correction of Certain Bite Anomalies with Particular Reference to the Maxillary Approach*'.

7.45 p.m. for 8.15 p.m. Formal Dinner (College Hall, Royal College of Surgeons).

Saturday, 12 *May*

9.45 a.m. Paper: Miss D. R. Ridley: '*Some Difficulties experienced in the Orthodontic Treatment of Patients with Cleft Lip and Palate*'.

10.45 a.m. Coffee.

11.15 a.m. Chairman: Mr. S. G. McCallin. Film: Mr. P. M. Benzies: '*Adaptive Functional Differences in Twins*'.

12.30 p.m. Luncheon.

2.30 p.m. Demonstrations: Dr. W. Russell Logan: '*Scoliosis*'. Mr. J. Angelman: '*Clinical Method of Measuring Skeletal Pattern*'. Mr. J. D. Atherton: '*Appliance Treatment of Unerupted Maxillary Canines*'. Mr. A. J. P. Cousins: '*Appliances in Cold Cure Acrylic*'. Mr. D. A. Dixon: '*Retention Techniques for Stabilizing the Cleft Palate Dentition*'. Mr. S. Haynes: '*A Teaching Demonstration on Expansion Screws, and the Andresen Appliance*'. Mr. G. B. Hopkin and Miss E. A. Mason: '*Indirect Band Construction for Orthodontic Appliances*'. Mr. G. A. James and Mr. G. S. Beagrie: '*The Care of Periodontal Tissue during Orthodontic Treatment*'. Miss R. Mears: '*Treated Cases*'. Miss M. N. Miller: '*Cases treated without Appliance*'. Mr. C. D. Parker: '*The Bodily

Retraction of Upper Incisor Teeth'. Mr. W. Stevenson: '*Treatment Aids*'. Mr. A. Westbrook: '*Activator Treatment in Class II Cases*'.
3.30 p.m. Tea.

ORDINARY MEETING, 8 October

An Ordinary Meeting of the Society was held at Manson House, 26, Portland Place, London, W.1, on Monday, 8 October, 1962, with the President, Dr. W. Russell Logan, in the Chair.

The Secretary read the Minutes of the Fifth Country Meeting held in Edinburgh on 11 and 12 May, 1962.

Apologies for absence were received from Mr. J. S. Rose, Mr. K. E. Pringle, and Professor T. C. White.

Two members, Miss C. M. McCall and Mr. A. J. Hardingham, whose election had been confirmed but who had not been introduced to the President, were introduced to the President.

The following candidates for membership were elected:—

Mr. D. F. Christy, L.D.S. R.C.S. (Eng.), 4, Scotland Bridge Road, New Haw, Weybridge, Surrey.

Mr. A. Cockburn, L.D.S. R.C.S. (Edin.), Glasgow Dental Hospital, Glasgow.

Mr. R. McKechnie, L.D.S., R.F.P.S., D.D.O., 5, Stanley Avenue, Paisley.

Miss M. E. A. Campbell-Wilson, B.D.S. (L'pool), D.Orth. R.C.S., 10, Manchester Road, Southport, Lancs.

Mr. W. J. Clarke, B.D.S. (St. Andrews), 304, Whitchurch Road, Cardiff.

Mr. J. R. Pettman, L.D.S. (Durham), D.Orth., D.D.O., 105, Tunstall Road, Sunderland.

The Secretary announced that an invitation had been received for members of the Society to attend the Inaugural Meeting of the Lindsay Club on 18 October, and that an invitation had been received from Captain Welsh, Dental Science Liaison Officer for the American Naval Forces in Great Britain, to attend a film show at the American Embassy on 15 October.

The President welcomed any visitors present and hoped that they would feel free to take part in any discussions.

The President then introduced Mr. D. S. Hayton-Williams, who read a short communication:—

'*Transplantation of Lower Third Molar to First Molar Site*'

Following the discussion of the short communication, the President said that the main business of the evening was the Chapman Prize Lecture. As members knew, a prize had been instituted in honour of Mr. Chapman, who was a founder-member of the Society. He was the second Secretary of the Society, from 1911 until 1924. He was President in 1925. Mr. Chapman was a very much loved and greatly honoured member of the Society and he was, in a way, a bridge with the past in that he must be one of the last surviving people in England to take Dr. Angle's class; so when Mr. Dixon gave the first Chapman Lecture, he followed in the apostolic succession.

He called on Mr. D. A. Dixon to deliver the first Chapman Lecture, entitled:—

'*Observations on Submerging Deciduous Molars*'

Following Mr. Dixon's paper, the President presented to him the Chapman Prize, together with a scroll. On the suggestion of the President, it was agreed that a telegram of good wishes should be sent to Mr. Harold Chapman.

ORDINARY MEETING, 12 November

An Ordinary Meeting of the Society was held at Manson House, 26, Portland Place, London, W.1, on Monday, 12 November, 1962, with the President in the Chair.

The Secretary read the Minutes of the Ordinary Meeting held on 8 October, 1962, which were approved and signed.

The President said it would be recalled that the Secretary had been asked to send a telegram of congratulation to Mr. Chapman on the occasion of the first Chapman Prize Essay. That action had been taken and a reply from Mr. Chapman had been received. The reply was then read.

The Secretary reported that apologies for absence had been received from Mr. D. Robertson-Ritchie and Mr. A. J. Hardingham.

The Secretary announced that the forthcoming Country Meeting was to be held on Thursday, Friday, and Saturday, 16, 17, and 18 May, 1963. On the Thursday afternoon, a research session was to be held in which research reports which could be delivered in not more than fifteen minutes were to be given.

There were no introductions of new members to the President.

The following candidates for membership were elected:—

Miss Frances J. Bigg, B.D.S., L.D.S., D.Orth. R.C.S., 56, Ormond Avenue, Hampton, Middlesex.

Mr. I. F. Davidson, B.D.S. (Glas.), F.D.S., D.Orth. R.C.S., 88, Pymmes Green Road, New Southgate, London, N.11.

Mr. A. J. Keniry, L.D.S. (L'pool), c/o 4, Risingholme Road, Harrow, Weald, Middlesex.

Mr. N. R. E. Robertson, B.D.S. (Glas.), H.D.D., D.D.O., R.F.P.S. (Glas.), Orthodontic Department, Turner Dental School, Bridgeford Street, Manehester 15.

Mrs. C. M. Thomson, L.D.S., D.D.O. (Glas.), Mansfield, 166, Garscadden Road, Glasgow, W.5.

Dr. N. M. Coval, B.A., D.D.S. (Columbia), 30, Westover Place, Lawrence, L.I., N.Y., U.S.A. (Corresponding Membership.)

Mr. R. C. Grossman, D.M.D. (Harvard U.), School of Dentistry, University of California Medical Center, Los Angeles 29, California. (Corresponding Membership.)

The President welcomed any visitors who were present and invited them to take part in the discussion.

The President said that it was a very pleasant duty indeed to introduce Professor J. I. P. James, Professor of Orthopaedic Surgery in the University of Edinburgh, who delivered the Sixteenth Northcroft Memorial Lecture, entitled:—

'*Bone Growth, Normal and Abnormal*'

ANNUAL GENERAL MEETING, 10 December

The Annual General Meeting of the Society was held at Manson House, 26, Portland Place, London, W.1, on Monday, 10 December, 1962, at 7 p.m., with the President, Dr. W. Russell Logan, in the Chair.

Minutes.—The Secretary (Mr. B. C. Leighton) read the Minutes of the Annual General Meeting held on Monday, 11 December, 1961. The Minutes were signed by the President as a correct record.

Apologies for absence were received from Mr. A. Westbrook and Mr. E. Breakspear.

Election of Officers and Councillors.—The following Officers and Councillors were elected:

President:	Mr. A. G. Taylor
Immediate Past President:	Dr. W. Russell Logan
President Elect:	Dr. W. J. Tulley
Senior Vice-President:	Professor C. F. Ballard
Vice-President:	Mr. A. J. Walpole Day
Councillors:	Mr. C. P. Briggs
	Mr. E. S. Broadway
	Mr. M. A. Burley
	Mr. A. C. Campbell
	Mr. D. A. Dixon
Treasurer:	Mr. J. S. Rose
Secretary:	Mr. B. C. Leighton
Editor:	Dr. J. R. E. Mills
Curator:	Mr. J. S. Beresford
Librarian:	Mr. D. I. Smith

Election of Auditors.—On a motion proposed by Mr. J. S. Beresford, Messrs. J. F. Pilbeam and P. H. Burke were elected as auditors.

The Report of the Treasurer.—The Treasurer (Mr. J. S. Rose), presenting his report, said that in presenting his first accounts he would like to begin by thanking the Society for the honour of being elected Hon. Treasurer.

Secondly, he would like to express his appreciation to his predecessor, Mr. J. S. Beresford, for the easy and efficient way in which he handed over the accounts. Everything was in such up-to-date order that his new job appeared deceptively simple. Mr. Beresford was a worthy successor to Mr. Chapman and he could only try to live up to the high standards that had been established.

This year, he had to report, the excess of income over expenditure had been reduced by about £250. This was mostly accounted for by the increase in cost of the Society's Transactions, and members would have noted that the reserve for this had been increased.

In last year's Hon. Treasurer's report, mention was made of the change in the Society's Investments. These changes were

now shown for the first time in the current balance sheet.

A new item was General Secretarial Expenses. The Society now had the service of a part-time secretary and the figure given represented only a period from June to September, 1962. In future years this figure would obviously be much higher.

He was grateful for the continued help of the Hon. Librarian for the increased income from the sale of the Society's TRANSACTIONS.

The TREASURER moved the rcception of the report, Mr. J. S. BERESFORD seconded, and the report was *adopted.*

A member said that, a few years previously, he had remarked that the Society seemed to be making rather a large profit and he wondered whether that profit could be put towards some original research. The following year, the Treasurer produced a loss. He was glad to see that that loss had not been repeated, but, having made that remark, he wished to congratulate the previous Treasurer and Council on keeping the Society's finances on an even keel, not showing too much profit and not showing a loss.

Report of the Secretary.—The SECRETARY (Mr. B. C. LEIGHTON) read his report, saying that he had once again to report an active year in which there had been further growth and development of the Society. Although osteoclastic activity had deprived the Society of 7 old members by resignation, this had been more than offset by the apposition of 31 new members. The net result of this growth had been to bring the membership to 519. In spite of a fall in the average attendance to 96, the Society had lost none of its vitality.

Recognizing the need for administrative development to keep pace with the growth of the Society and its activities, the Council had authorized the appointment of a part-time assistant to undertake clerical duties for all of the executive officers. This had already eliminated some duplication of work, and it was hoped that it would lead to a better co-ordination of the duties of these officers.

In spite of interferenee with air travel by a strike, the Country Meeting was well attended. The hospitality shown by their colleagues in Scotland, and the excellent banquet in the Royal College of Surgeons of Edinburgh, would be especially remembered by those present.

In response to efforts on the part of the Council to encourage more papers on the practical aspects of orthodontics, the proportion of these had increased, particularly at the Country Meeting. The length of the discussions confirmed the popularity of this policy. He moved its reception and the report was *adopted.*

Report of the Editor.—The EDITOR (Dr. J. R. E. MILLS), reading his report, said that he took on the duties of Editor a year ago and had no cause to change the excellent policies of his predecessor.

The Society's TRANSACTIONS had continued to be published in the *Dental Practitioner*, together with an account of the ensuing discussion, and excellent relations had been maintained with the publishers, Messrs. John Wright & Sons Ltd. Papers were published about five months after delivery, which compared quite favourably with other learned societies, although it might be possible to reduce this dclay slightly.

The 1961 TRANSACTIONS were almost ready for distribution and should be in members' hands immediately after Christmas.

Members having material suitable for publication were reminded that the Council was always willing to consider such material, and members were advised to write to the Secretary, giving the title of the proposed paper, together with a brief abstract to indicate its nature. Papers of both a theoretical and practical nature were welcome, but the work involved should be original and should not have been published elsewhere.

He moved its reception. The report was *adopted.*

Report of the Librarian.—The LIBRARIAN (Mr. D. I. SMITH), presenting his report, said that in addition to acquiring and lending orthodontic books and periodicals, the Library sells current and past TRANSACTIONS of the Society. The demand for these TRANSACTIONS continued to increase and it was an encouraging example of the interest shown in the Society.

He repeated the Librarian's yearly request for any unwanted TRANSACTIONS for the following years: 1954, 1958, 1959.

He moved its reception. The report was *adopted.*

Report of the Curator.—The CURATOR (Mr. J. S. BERESFORD), presenting his report, said that the Museum was still housed next door in the Institute of Public Health.

The Society was grateful to Dr. L. M. Clinch for presenting models and radiographs illustrating a case in which a supernumerary tooth was geminated to a lower premolar and in which some upper teeth were congenitally absent.

He moved its reception. The report was *adopted.*

The PRESIDENT said that members should remind themselves of the amount of work done by the office-bearers of the Society. With the increasing tempo of life, there seemed to be more and more work done by them.

He wished from the Chair to propose a very hearty vote of thanks to the office-bearers for their year's work.

The vote of thanks was carried by acclamation and the Annual General Meeting terminated.

ORDINARY MEETING, 10 December

AN ORDINARY MEETING of the Society was held at Manson House, 26, Portland Place, London, W.1, on Monday, 10 December, 1962, following the Annual General Meeting. The President, Dr. W. Russell Logan, occupied the Chair.

The Minutes of the Ordinary Meeting held on Monday, 12 November, 1962, were read by the Secretary and signed as a correct record.

Two members, whose election had been confirmed, were introduced to the President; they were Miss F. J. Bigg and Mr. I. F. Davidson.

The PRESIDENT said that a very pleasant duty devolved on him, and he was particularly glad that it had happened at the last meeting of his presidency. The Council had authorized him to propose that the Society give an Honorary Membership to an old and valued member of the Society, Mr. Norman Gray.

Mr. Gray joined the Society in 1928; he was President in 1945, his year of presidency being a very memorable one. He had done a tremendous amount of work for the Society, and it was therefore proposed to offer him Honorary Membership. (Applause.)

Mr. GRAY said that he had heard of Honorary Members and had seen Honorary Members but he had never dreamt that he would ever be one. He thanked members very much and wished the Society success.

Lt.-Col. E. S. Foster, L.D.S.(Sheff.), H.D.D. R.C.S. (Edin.), F.D.S. R.C.S. (Eng.), c/o Q.A. Military Hospital, Millbank, London, S.W.1., was elected a member.

The PRESIDENT then introduced Dr. G. B. Hopkin, who read his paper entitled:—

'*A Roentgenographic Cephalometric Analysis of Treatment and Growth Changes in a Series of Cases of Mesioclusion*'

The PRESIDENT proposed a vote of thanks to Dr. Hopkin for his paper and to Miss Clinch for opening the discussion.

Vote of Thanks to Retiring President.—Mr. J. H. GARDINER said it gave him great pleasure to propose, on behalf of those present, a vote of thanks to the Retiring President. Dr. Logan had brought to the office dignity, integrity, and experience, but he had also brought courage. He was told that if Dr. Logan felt a certain course was right, he proceeded to fight for it and this he had done, not only to the benefit of the Society but as a Lieutenant-Colonel in the landings in Normandy some years ago. He asked those present to support a hearty vote of thanks to the Retiring President which was carried by acclamation.

THE PRESIDENT'S VALEDICTORY ADDRESS

The PRESIDENT said that the next item on the brief which the Secretary had put before him was a Valedictory Address, but he was sure that at that late hour no-one would wish to hear such an address so he would cut it very short. He just wished to thank members for the great honour they had done him in allowing him to preside over their deliberations for the past year. It was an honour which he would treasure for the rest of his life.

He offered grateful thanks to the office-bearers who had put up with him for a year, and, in particular, he wished to offer his most grateful thanks and admiration to the Secretary, who had done everything he could; he did a tremendous lot and spent a great deal of time and, indeed, loving care in the running of the Society and, in particular, the ordering of the Presidents.

If he had to say anything in the way of a Valedictory Address, it would be in the terms of Sir Robert Hutchinson's prayer which went rather as follows:—

'From inability to let well alone, and too much zeal in what is new and contempt for what is old; from putting knowledge before wisdom, science before art and cleverncss before commonsense; from treating patients as cases and from making the cure of a disease more grievous than its endurance, Good Lord deliver us.'

His next pleasant duty was to induct Mr. A. G. Taylor to the Chair.

Mr. Taylor said that, as Dr. Logan had, he would lean very heavily on the shoulders of the Secretary. His brief said that the new President would close the meeting with the announcement of his Presidential Address, '*The Future of the Society*'. That would be delivered on Monday, 14 January, 1963.

THE BRITISH SOCIETY FOR THE STUDY OF ORTHODONTICS

Balance Sheet and
Income and Expenditure Account

FOR THE YEAR ENDING SEPTEMBER 30, 1962

FREDK. B. SMART & COMPANY, CHARTERED ACCOUNTANTS
22 Queen Street, London E.C.4

The British Society for the Study of Orthodontics

INCOME AND EXPENDITURE ACCOUNT for the year ended 30th September, 1962

1961 £	£		£ s. d.	£ s. d.
11		To *Museum Rent*		10 10 0
		,, *Meeting Expenses:—*		
	47	Hire of Hall	46 13 0	
	68	Refreshments	70 16 4	
	98	Reporting	134 1 0	
	5	Lantern and Films	8 10 0	
	30	Country Meeting	40 2 6	
	26	Northcroft Memorial Lecture	26 5 0	
274	——		——————	326 7 10
		,, *Printing:—*		
	679	Publications	964 4 7	
		General Printing and		
	158	Stationery	136 17 8	
837	——		——————	1101 2 3
3		,, *Library and Journals*		18 9 0
52		,, *Postage*		65 7 8
—		,, *General Secretarial Expenses*		21 3 4
23		,, *Honoraria*		52 10 0
26		,, *Accountancy*		26 5 0
4		,, *Insurance*		4 3 6
3		,, *Sundry Expenses*		4 7 4
		,, *Depreciation of Furniture and*		
137		*Equipment*		30 16 0
		,, *Excess of Income over Expenditure for the year*		
542				294 7 1
£1912				£1955 9 0

1961 £	£		£ s. d.	£ s. d.
		By *Members' Subscriptions:—*		
	1462	1962 Subscriptions	1536 1 1	
	65	Arrears Collected	2 10 0	
1527	——		——————	1538 11 1
158		,, *Sale of Transactions*		182 17 9
		,, *Interest Received and Accrued:—*		
	32	Savings Certificates	32 1 8	
	17	$2\frac{1}{2}\%$ Consolidated Stock	8 12 8	
	20	(4% Consolidated Stock)	— — —	
		$5\frac{1}{4}\%$ Hertfordshire C.C.		
	19	Stock (net)	19 5 10	
		$5\frac{1}{4}\%$ Corporation of London		
	16	Stock (net)	16 1 8	
	22	3% Funding Stock	21 13 8	
	50	5% Defence Bonds	50 0 0	
	15	Post Office Savings Bank	16 0 10	
	—	Bank Deposit Interest	1 17 6	
		J. & P. Coats, Patons &		
	—	Baldwins Ltd.	12 6 7	
		City of London Real Property		
	—	Co. Ltd.	5 19 9	
		British Insulated Callenders		
	—	Cables Ltd.	9 6 2	
	—	Royal Insurance Co. Ltd.	4 12 0	
191	——		——————	197 18 4
		,, *Income Tax Recoverable* to		
36		5th April, 1962		36 1 10
£1912				£1955 9 0

The British Society for the Study of Orthodontics

BALANCE SHEET as at 30th September 1962

1961 £	£		£ s. d.	£ s. d.
		Accumulated Fund:—		
		Balance at 1st October, 1961 ..	4959 14 10	
		Add: Excess of Income over Expenditure for the year	294 7 1	
			5254 1 11	
		Less: Loss on Sale of Investments	497 1 1	
4960				4757 0 10
		Creditors and Reserves:—		
	1700	Publications printing reserves (estimated by the Hon. Treasurer) ..	1850 0 0	
	26	Northcroft Memorial Lecture (2 years)	52 10 0	
	13	Hire of Hall	13 10 0	
	10	Museum Rent	9 12 6	
	23	Subscriptions in Advance ..	28 16 0	
	5	Hon. Secretary Petty Cash Account	5 13 2	
	26	Accountancy	26 5 0	
1803				1986 6 8
£6763				£6743 7 6

J. F. PILBEAM
ALAN C. CAMPBELL } *Hon. Auditors*
J. S. ROSE, *Hon. Treasurer*

1961 £	£		£ s. d.	£ s. d.
		Furniture and Equipment:—		
		Balance at 1st October, 1961 ..	150 16 0	
		Less: Depreciation	30 16 0	
151				120 0 0
		Investments at Cost:—		
	959	1200 National Savings Certificates plus accrued interest	991 5 0	
	576	(£691 5s. 10d. $2\frac{1}{2}$% Consolidated Stock)	— — —	
	485	(£500 4% Consolidated Stock) ..	— — —	
	1000	£1180 3% Funding Stock 1959/69	1000 5 0	
	1000	£1000 5% Defence Bonds ..	1000 0 0	
	597	£600 $5\frac{1}{4}$% Hertfordshire County Council, 1965	597 9 6	
	509	£500 $5\frac{1}{4}$% Corporation of London 1976/79	508 10 9	
	—	230 J. & P. Coats, Patons & Baldwins Ltd. £1 Ordinary Shares ..	496 17 10	
	—	£115 City of London Real Property Co. Ltd. Ordinary Stock ..	478 17 9	
	—	£160 British Insulated Callenders Cables Ltd. Ordinary Stock ..	484 4 2	
	—	£50 Royal Insurance Co. Ltd. Stock	478 10 0	
5126		(Approximate Market value £5952)		6036 0 0
36		*Income Tax Recoverable*		36 1 10
		Cash at Bank:—		
	479	Westminster Bank Ltd.	333 9 3	
	970	Post Office Savings Bank	16 4 5	
	—	Deposit Account	200 0 0	
1449				549 13 8
	1	*Cash in Hand*		1 12 0
£6763				£6743 7 6

Certified in accordance with the Books and Vouchers of the Society.
We have verified the Investments and Cash at Bank.

FREDK. B. SMART & CO.,
Chartered Accountants,
22, Queen Street, London, E.C.4.

9th November, 1962.

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